SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Sewage Pumping Fundamentals—Hands

Chlorine Demand Determination—Nusbaum and Meyerson

Sewage Treatment Design for Metal Wastes—
Mitchell, Cassanos and Okun

Rendering Wastes Treatment—Granstrom

Important Priorities Notice—See Page 1054

AUGUST, 1951—VOL. 23, No. 8

Make Plans to Attend

TWENTY-FOURTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

MUNICIPAL AUDITORIUM

ST. PAUL, MINN.

October 8-11, 1951

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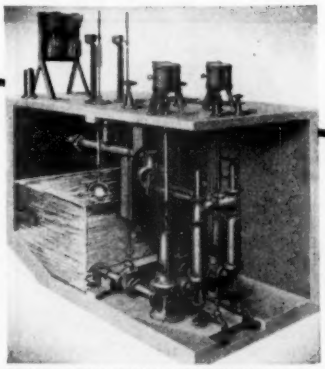

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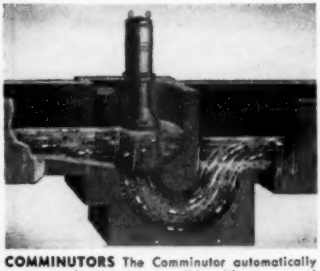

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SEWAGE AND INDUSTRIAL WASTES

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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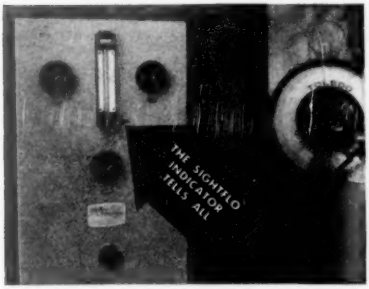

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HOW TO MEASURE TRADE WASTES ACCURATELY

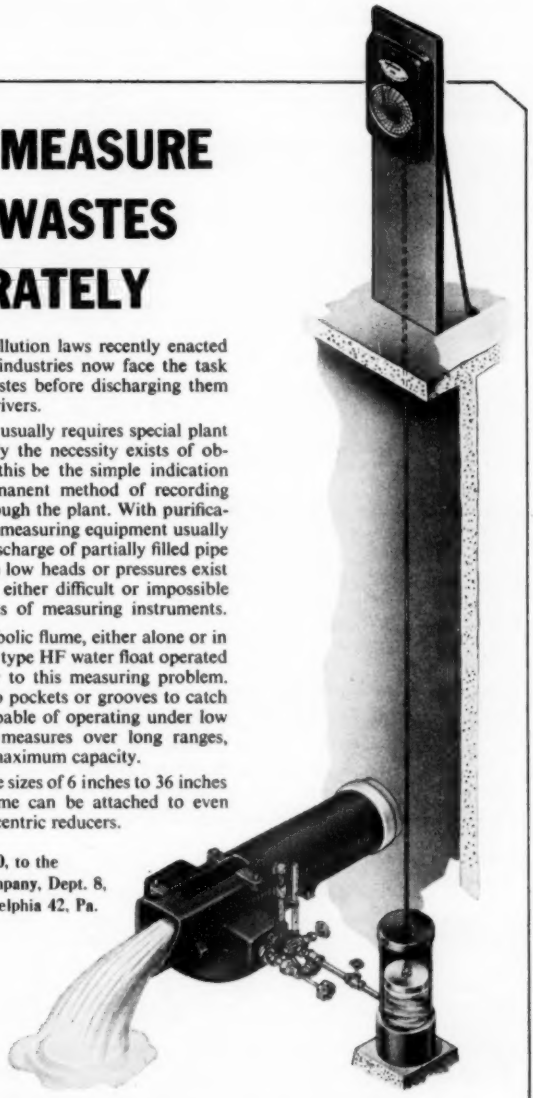
In accordance with anti-pollution laws recently enacted by numerous states, most industries now face the task of purifying their plant wastes before discharging them into adjacent streams and rivers.

This purification process usually requires special plant construction, and invariably the necessity exists of obtaining flow data, whether this be the simple indication of flow rate or a more permanent method of recording and totalizing the flow through the plant. With purification processes of this kind, measuring equipment usually is located at the point of discharge of partially filled pipe or in open channels, where low heads or pressures exist and where measurement is either difficult or impossible when using standard forms of measuring instruments.

The Simplex type S Parabolic flume, either alone or in conjunction with a Simplex type HF water float operated meter, is the ready answer to this measuring problem. Compact in design, with no pockets or grooves to catch sediment or solids, and capable of operating under low flow conditions, the unit measures over long ranges, from maximum to 5% of maximum capacity.

Available in standard pipe sizes of 6 inches to 36 inches diameter inclusive, the flume can be attached to even larger sizes by means of eccentric reducers.

Write for Bulletin 210, to the
Simplex Valve & Meter Company, Dept. 8,
6719 Upland Street, Philadelphia 42, Pa.



IT'S SIMPLEX
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Association	*Place*	*Time*
Canadian Institute on Sewage and Sanitation	Royal York Hotel, Toronto, Ont.	Aug. 20–22, 1951
Pennsylvania Sewage and Industrial Wastes Association	State College, Pa.	Aug. 22–24, 1951
Iowa Sewage Works Association	Hotel Tall Corn, Marshalltown, Iowa	Sept. 11–13, 1951
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Kentucky Hotel, Louisville, Ky.	Sept. 17–19, 1951
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 19–21, 1951
South Dakota Water and Sewage Works Conference	Charles Gurney Hotel, Yankton, S. Dak.	Sept. 19–21, 1951
Rocky Mountain Sewage Works Association	Cosmopolitan Hotel, Denver, Colo.	Sept. 26, 1951
North Dakota Water and Sewage Works Conference	Gardner Hotel, Fargo, N. Dak.	Sept. 26–28, 1951
Missouri Water and Sewerage Conference	Robidoux Hotel, St. Joseph, Mo.	Sept. 30–Oct. 2, 1951
West Virginia Sewage and Industrial Wastes Association	Daniel Boone Hotel, Charleston, W. Va.	Oct. 3–4, 1951

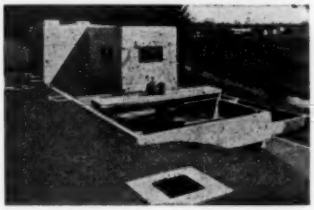
Federation of Sewage and Industrial Wastes Associations in conjunction with Central States Sewage and Industrial Wastes Assn.
Municipal Auditorium, St. Paul, Minn.
October 8–11, 1951

Florida Sewage and Industrial Wastes Association	Sheraton Plaza Hotel Daytona Beach, Fla.	Oct. 28–31, 1951
New England Sewage Works Association	Sheraton-Biltmore Hotel, Providence, R. I.	Nov. 6–7, 1951
North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951
Oklahoma Water, Sewage and Industrial Waste Conference	Oklahoma A. & M., Stillwater, Okla.	Dec. 3–7, 1951
Texas Water and Sewage Works Association	Texas A. & M., College Station, Texas	March 9–13, 1952
Arkansas Water and Sewage Conference	Engineering Building, University of Arkansas, Fayetteville, Ark.	April 7–9, 1952

Ideal for small communities, isolated institutions, outlying plants

—*Activated Sludge Process*
or Biological Trickling Filter

YEOMANS SEWAGE TREATMENT PLANTS



THE "PACKAGE" AERIFIER

Many small communities and outlying institutions, compelled to purify wastes but lacking an ample supply of diluting water, have found in the Yeomans "Package" Aerifier an ideal answer to a critical problem.

Compact, exceedingly efficient in purification, unique for low construction and operation costs, this activated sludge plant provides aeration and final sedimentation in a single concrete unit. Operation is as simple as possible, with supervision limited to routine check-up. Every installation includes final adjustment, initial tested operation, thorough training of operators and continuing counsel from Yeomans engineers.

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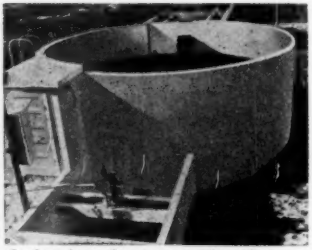

Operating in conjunction with a primary sedimentation tank, the Yeomans "Water-Wheel" Distributor applies settled sewage to a trickling filter—with unfailing dependability. Sewage flows into the rotating trough, and is spread evenly on the filter bed through V-notches and spreader plates. The trough is actuated by a water-wheel and bevel gearing. Filter beds range from 5-foot to 25-foot diameters; and the entire area is effective for treatment. Continuous positive distribution is assured at all rates of flow—which does away with the need for dosing chambers and siphons. There is none of the clogging and cleaning of spray nozzles often required with reaction distributors; and elimination of accessories saves as much as the entire cost of the complete Water-Wheel installation. Maintenance is extremely simple. Numerous Water-Wheel plants—small communities, hospitals, airports, industrial plants—provide impressive proof of this unit's extraordinary efficiency.

Helpful engineering data on these Yeomans plants will be sent promptly upon request—no obligation.

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The new Fairbanks-Morse Pomona external sleeve bearing assembly gives you *plenty* of advantages in efficient, economical deepwell turbine pump performance.

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There is no chance for liquid entry between shaft and sleeve bearing. Friction and shaft bearing losses are reduced to the minimum. Worn sleeves can be easily and inexpensively replaced in the field.

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Designs from engineers' notebooks

Sludge Digestion Tank Relief Valve in EVERDUR

This relief valve was especially developed by Nussbaumer, Clark & Velzy of New York and Buffalo to relieve upward pressure on a concrete sludge digestion tank when ground water level becomes so high that flotation of the tank might otherwise occur.

The engineers point out that the critical elements in this unit and its application are the valve seat and the restraining bolts. For these, EVERDUR* was specified because of its excellent resistance to corrosion and its great strength.

Everdur (ANACONDA Copper-Silicon Alloys) long ago proved its economy and durability in water and sewage works equipment under severely corrosive operating conditions. These easily welded alloys make possible the use of lightweight wrought assemblies which provide exceptional ease of operation as well as long, rust-free service.

Our Technical Department will gladly help you select the most suitable Everdur alloy for your equipment or corrosion problem. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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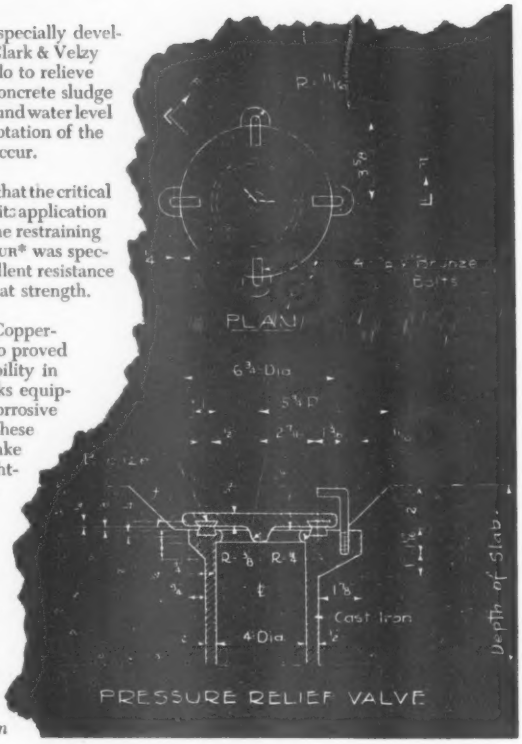

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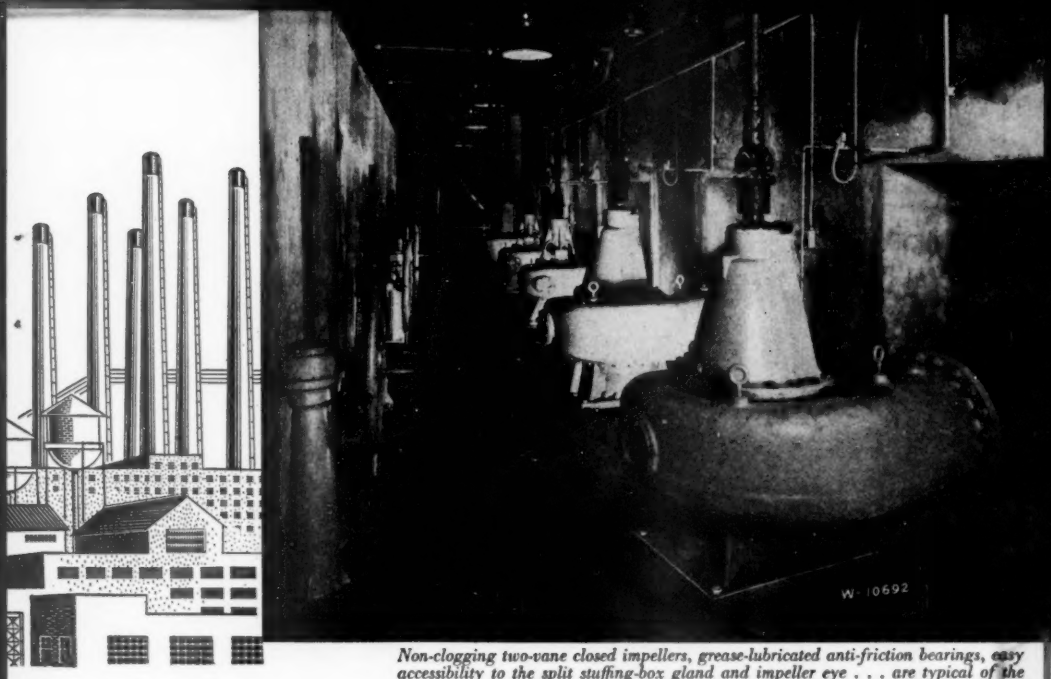

Non-clogging two-vane closed impellers, grease-lubricated anti-friction bearings, easy accessibility to the split stuffing-box gland and impeller eye . . . are typical of the many Worthington MIXFLO *features assuring low-cost, trouble-free sewage pumping.*

How is Bridgeport's Sewage Pumped?

It's full of industrial waste . . . a problem built for Worthington Pumps

Here's another municipality which has turned its sewage pumping over to Worthington—100%.

These five Worthington Vertical MIXFLO sewage pumps are located in Bridgeport's Westside sewage plant—installed in 1946. Three are 20-inch, two are 16-inch MIXFLOS.

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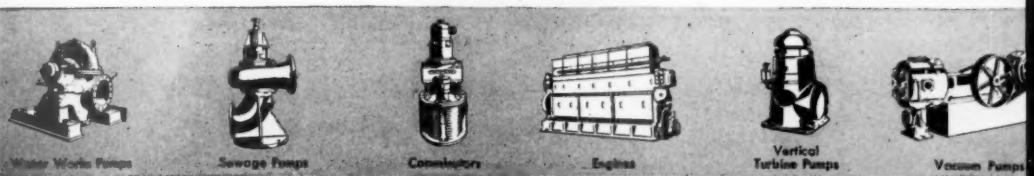

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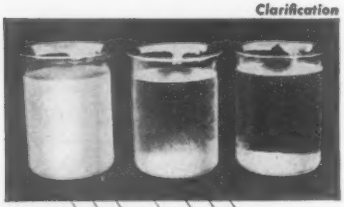

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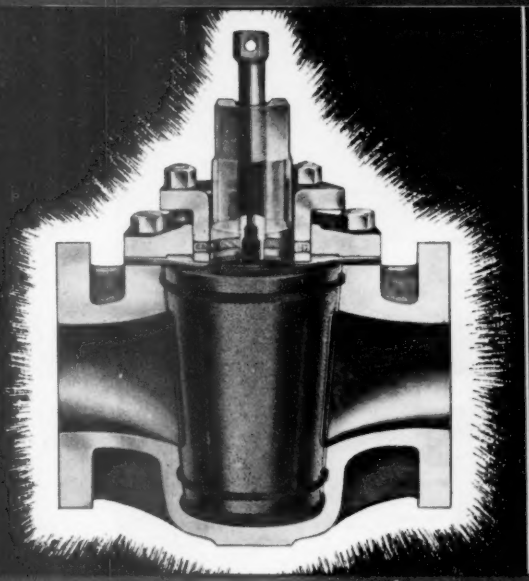

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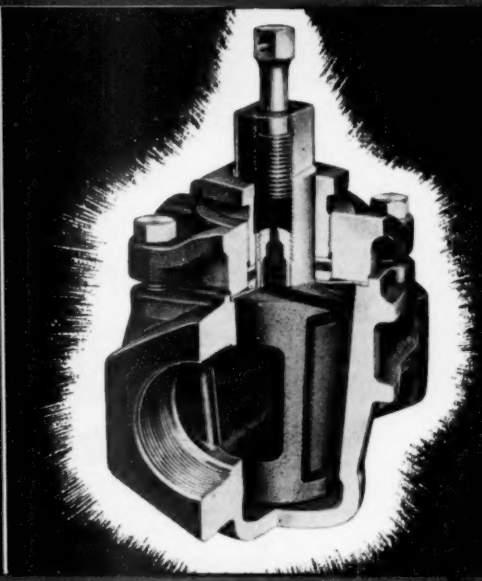

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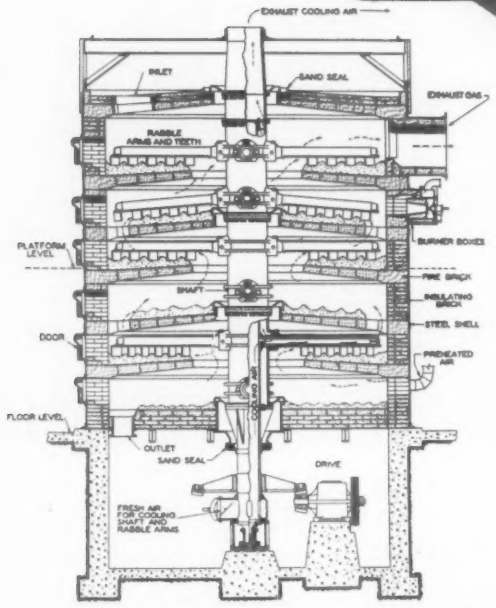

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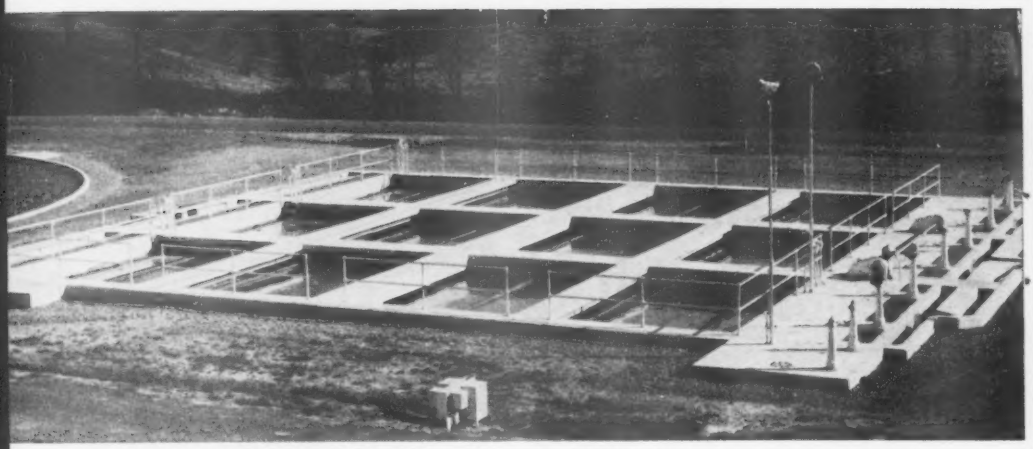

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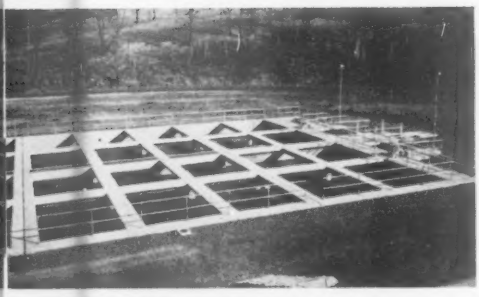

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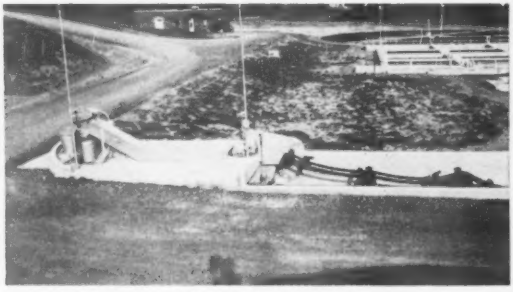

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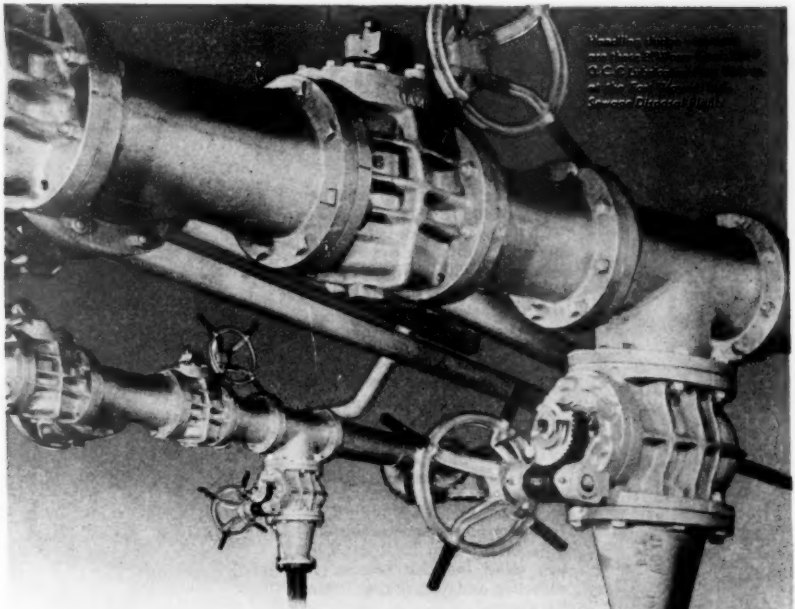

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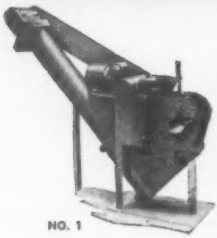

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 23 **AUGUST, 1951** **Number 8**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
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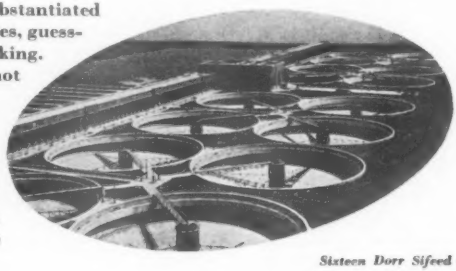

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Sewage Works

FACTORS AFFECTING THE QUANTITY OF SLUDGE PRODUCTION IN THE ACTIVATED SLUDGE PROCESS *

By H. Heukelekian, H. E. Orford, and R. Manganelli

Although the activated sludge process has been used for many years and the literature on this process is voluminous, there is surprisingly little information available about the amount of excess sludge produced. Sewage plant operating records are also disappointing as a source of information on the subject. This may be expected perhaps, because in many activated sludge plants excess activated sludge is mixed with primary sludge and the identity of the activated sludge is lost. Even with activated sludge plants having no primary settling, it is difficult to obtain correlated information concerning the amount of sludge produced under varying conditions of treatment.

It has been assumed that the amount of excess sludge produced decreases as the sludge oxidation increases. The experience of many plant operators and investigators, as well as the term "wet combustion" of activated sludge, supports this expectation. On the other hand, some investigators, such as Lumb (4), report that the oxidation or wet combustion of activated sludge solids is negligible.

Because of the scarcity of information in the literature on the subject, laboratory experiments were performed to measure the amount of excess activated sludge produced under various operating conditions and with varying sewage characteristics.

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

Laboratory Procedure

Equipment

The activated sludge mixtures were aerated in lucite, double tube, aeration chambers of 5.5-l. capacity (Figure 1). Air rising from a diffusor in the bottom of the inside tube caused the liquid to flow up through the inside tube and down through the space between the two tubes. The inside tube was supported on short legs ¼ in. off the bottom so that circulation could be completed. The double tube circulation system was adopted so that the sludge could be kept in suspension with air volumes of 1 cu. ft. per gal. used in the experiments.

Air volumes were measured through calibrated capillary tube orifices equipped with differential water manometers.

Operation

All experiments were performed on a batch basis in the laboratory at room temperature. Sewage was fed three times a day, at 9:00 A.M., 4:00 P.M., and 10:00 P.M. Although this schedule did not allow for a uniform aeration period, the procedure of operation was not materially different from that of many sewage plants with low night loadings. The mixed liquor was drained from the tubes and allowed to settle 30 min. in 6-in. diameter glass jars. Then 3.8 l. of supernatant liquor was carefully siphoned off each jar and replaced with settled sewage. This procedure gave a 31 per cent sludge

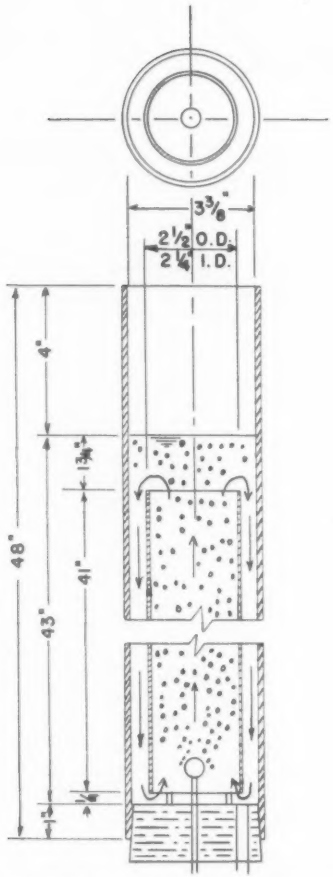

FIGURE 1.—Sketch of double tube aeration unit used in activated sludge experiments.

return, which might be considered high, but was necessary because of the sludge volume in the higher concentrations used. After the sewage was mixed the mixed liquor was returned to the aerator.

Sampling

Raw sewage was collected every second day, settled for 30 min., and the supernatant decanted and stored in the refrigerator. Sewage samples were composited over 24-hr. periods and used for each sewage addition.

Activated Sludge

All waste activated sludge was removed, before settling, as mixed liquor. Samples of the waste mixed liquor were taken from each aeration tube at the end of each aeration period for a suspended solids determination. In this way the mixed liquor suspended solids and the sludge solids wasted could be determined from the same sample.

Analyses

To obtain the necessary information to determine the sludge solids accumulation, routine analyses were made on sewage for suspended solids, volatile suspended solids, and 5-day B.O.D.; also, suspended solids and volatile suspended solids of the mixed liquor. All effluents consistently showed less than 12 p.p.m. B.O.D. and 10 p.p.m. suspended solids and the variations encountered were within the limits of experimental accuracy. Differences in the B.O.D. and suspended solids of the effluent were not great enough to affect the suspended solids and B.O.D. relationships involved in the oxidation of activated sludge.

Results

Five experiments were conducted, each with three different mixed liquor suspended solids concentrations. Settled sewages from four different municipalities were used in the first four runs. In the fifth run the sewage was diluted in proportion to the mixed liquor suspended solids concentration in order to maintain a constant sludge age; the highest concentration received the undiluted sewage. Each run was made with a different batch of returned sludge obtained from an activated sludge plant.

The characteristics of the sewages employed in the different experiments are given in Table I. The suspended

TABLE I.—Average Characteristics of Sewage Employed in Different Experiments

Run No.	Source of Sewage	Susp. Solids		B.O.D. (p.p.m.)	Ratio $\frac{\text{B.O.D.}}{\text{S.S.}}$
		Total (p.p.m.)	Vol. (%)		
1	South River	113	78	157	1.5
2	Plainfield	178	83	315	1.7
3	Highland Park	160	86	246	1.5
4	Marlboro	97	81	170	1.7
5	South River	177	—	189[1]	1.1

[1] Full strength sewage before dilution.

solids and B.O.D. concentrations of the different sewages varied considerably, with nearly constant ratios of B.O.D. to suspended solids. The exception was the sewage used in the fifth experiment.

The concentrations of suspended solids in the mixed liquors maintained in these experiments are given in Table II, together with the accumulated suspended solids in milligrams per day and pounds per million gallons. The suspended solids in the mixed liquor in low, medium, and high concentrations, as well as sludge accumulations, varied considerably in the different experiments, but as a crude approximation these values are averaged for four experiments. The results show that as a first approximation there is an inverse relationship between suspended solids in the mixed liquor and the sludge build-up. It is evident that the actual quantity of sludge build-up in the activated sludge process cannot be definitely fixed and that it varies greatly with the suspended solids concentration of the mixed liquor and sewage strength. Other variables play a role. When the results from the special experiment were omitted, the suspended solids build-up varied from 300 to 1,270 lb. per mg. of sewage containing various concentrations of mixed liquor. On the basis of the average of the four experiments, the values are 945, 850, and 640 lb. per m.g., respectively, for the low, medium, and high suspended solids concentrations in the mixed liquors.

The gross relationship of the individual runs between the suspended solids accumulation and mixed liquor suspended solids concentration is shown in Figure 2. Disregarding, momentarily, the results from the fifth run, one finds a general relationship and a general trend of decreasing sludge build-up with increasing mixed liquor suspended solids concentrations. The Plainfield sewage (run 2) seemed to be least affected by mixed liquor concentration. The other three sewages are in fair agreement in respect

TABLE II.—Average Characteristics of Activated Sludge

Run No.	Susp. Sol. in Mixed Liquor (p.p.m.)			Susp. Sol. Accumulated (m.g./day)			Susp. Sol. Accumulated (lb./m.g.)		
	Low	Med.	High	Low	Med.	High	Low	Med.	High
1	1,078	1,740	3,110	1,108	913	522	810	668	382
2	794	1,635	2,900	1,660	1,731	1,507	1,215	1,268	1,102
3	730	1,554	2,479	1,375	1,305	1,050	1,050	954	768
4	645	2,017	3,175	966	706	415	708	516	304
5	990	2,029	3,095	192	424	664	140	310	486
Av. (1–4)	812	1,738	2,916	1,277	1,164	873	945	850	640

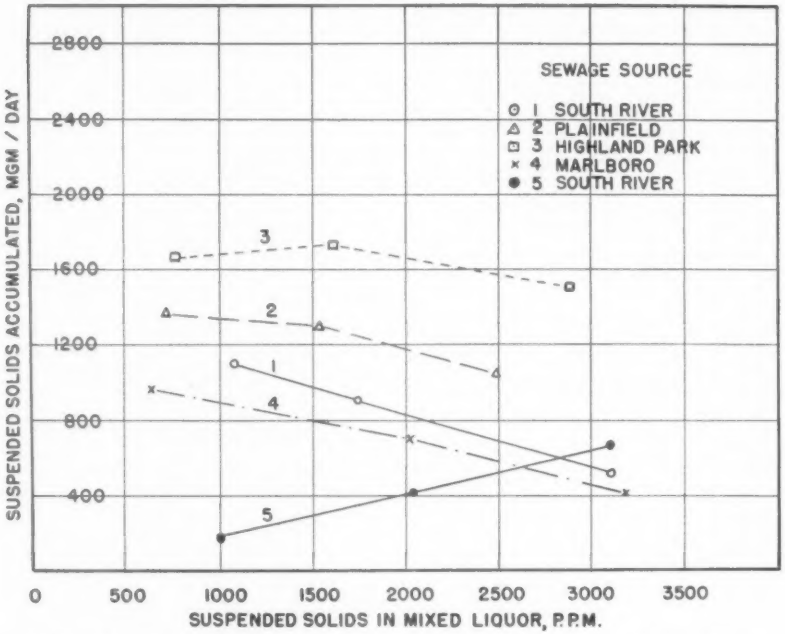

FIGURE 2.—Relationship between suspended solids accumulation and mixed liquor suspended solids concentration.

to the trend, but the levels for corresponding concentrations are different. In other words, the mixed liquor concentration is only one of the factors in determining the amount of sludge build-up. The opposite trend obtained with South River sewage (No. 5) can be attributed to the factor of strength of sewage, as the ratio of sewage solids to mixed liquor solids was held constant by dilution of the sewage for low, medium, and high mixed liquor concentrations. With the same load in relation to activated sludge, the more concentrated sewage produced a higher sludge build-up than the diluted sewage. Therefore, the results from this special experiment cannot be considered as contradictory to the other runs.

To eliminate the effect of variations in the concentration of suspended solids in the various sewages employed in the different experiments, the results were recalculated on the basis of suspended solids accumulated per unit quantity of suspended solids fed, and plotted as a function of mixed liquor suspended solids concentration (Figure 3). A better agreement between the four experiments is evident when the effect of suspended solids concentration of mixed liquor is taken into account. Plainfield sewage (No. 2) is again out of line, but to a lesser extent. There is a trend toward lower build-up of sludge, especially between the medium and high mixed liquor suspended solids concentrations. For a given sewage there is an approximate inverse relationship between the sludge accumulated per unit amount of sewage suspended solids and the mixed liquor concentrations. Hence, the differences in the level of sludge accumulation with different sewages

noted in Figure 2 were mainly due to the differences in the suspended solids concentrations of the sewages fed. The build-up of sludge for the three sewages which are in close agreement varied from 0.75 to 0.85 units per unit of suspended solids fed at 1,000 p.p.m. mixed liquor concentration to 0.65 unit at 2,000 p.p.m. and 0.4 at 3,000 p.p.m.

The results from run No. 5 fall in a special category. The sludge build-up per unit amount of suspended solids in the sewage treated was constant, irrespective of mixed liquor suspended solids concentration; moreover, it was at a much lower level than the values obtained from the other four runs. The first of the deviations from the general pattern can be explained because there was a constant relationship between the suspended solids in the treated sewage and the active biological material and, therefore, the concentration of the mixed liquor cannot be expected to affect the amount of sludge build-up. For an explanation of the deviation concerning the lower level of sewage build-up, a further analysis of the results is needed.

The amount of sludge build-up per unit of suspended solids in treated sewage can also be compared on the basis of sludge age, for example, as a function of the ratio of the amount of suspended solids in the mixed liquor to the amount of suspended solids in treated sewage. In such a comparison the amount of sludge build-up per unit amount of food (suspended solids) is correlated with the amount of active biological material in relation to the amount of food (suspended solids). An analysis of the results based on such a relationship is given in Figure 4. An even closer agreement of the slopes and magnitudes than in the previous comparisons is obtained. In other words, the quan-

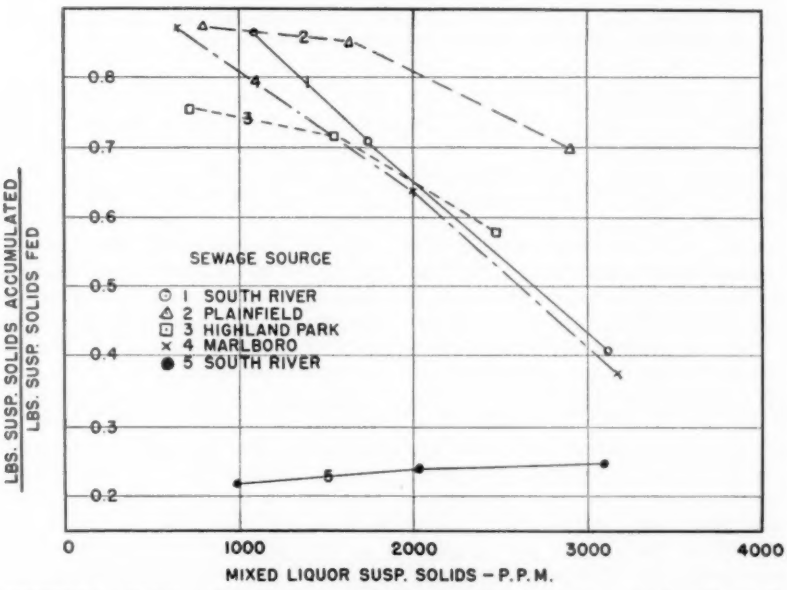

FIGURE 3.—Relationship between suspended solids accumulation, expressed as lb. per lb. of suspended solids fed, and the mixed liquor suspended solids concentration.

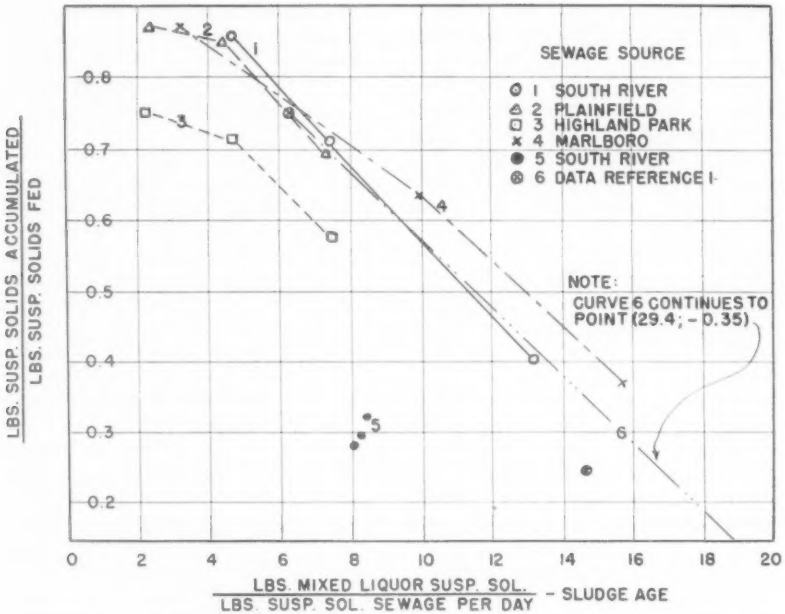

FIGURE 4.—Relationship between suspended solids accumulation, expressed as lb. per lb. of suspended solids fed, and the mixed liquor suspended solids, expressed as lb. per lb. of suspended solids fed (sludge age on suspended solids basis).

tity of sludge build-up is not only a function of (a) sewage strength (suspended solids), and (b) mixed liquor suspended solids concentration, but also the relationship between (a) and (b). To express it differently, the amount of sludge build-up per unit amount of suspended solids in the sewage treated is a function not merely of mixed liquor suspended solids concentration, but more closely of the relationship of the mixed liquor suspended solids to the sewage treated; for example, sludge age. It is significant that in experiment No. 5, where the sludge age was kept constant by artificially diluting the sewage in the same ratio as the suspended solids in the mixed liquor, the values obtained are in very close agreement. In other words, with the same sludge age, nearly constant sludge build-up is obtained. The fact that the values obtained for experiment No. 5 are lower than the values for corresponding sludge ages in the other experiments indicates that there is still another variable not yet considered. A sludge age of 5 days results in approximately 0.85 unit of suspended solids build-up per unit of suspended solids fed, whereas a sludge age of 10 days results in about 0.6 unit of solids build-up per unit of suspended solids fed.

Data published previously (2), designated as curve No. 6 in Figure 4, are plotted on the basis of the same units of expression. The sludge ages obtained in the previous work were 6, 15, and 39 days. The first two sludge ages are within the scale of the graph and fit in with the results obtained in the present study. The slope of the line obtained by connecting the values

for 6- and 29-day sludge ages coincides closely with the slopes obtained in the present study.

The previous study was for the purpose of measuring activated sludge oxidation, and solids accumulation data were incidental. It is interesting to note that the solids accumulation at 29.4-day sludge age is a negative value and actually represents a solids loss, or destruction. It is possible to have such a low amount of sewage food that there will be no excess activated sludge, and even sludge destruction. The sludge becomes over-oxidized, however, and begins to disintegrate before this point is reached. Also, such low loadings are generally impractical and are of only academic interest.

The analyses of the results so far have been upon the basis of the suspended solids of the sewage treated. The B.O.D. of the sewage, however, may be a more significant factor in the quantity of sludge build-up than the suspended solids, because it measures both suspended and dissolved organic material. When the suspended solids accumulated per unit amount of B.O.D. fed (Figure 5) are plotted against the quantity of mixed liquor suspended solids per unit amount of B.O.D. fed per day, a straight line relationship is obtained for the four experiments; namely, decreasing suspended solids build-up per unit amount of B.O.D. fed with increasing sludge age on the basis of B.O.D. The level of the line obtained from experiment No. 1 with South River sewage is considerably higher than the level obtained from the other experiments. It is significant to note that the points for experiment No. 5 are bunched together and fall within the range of values obtained from the

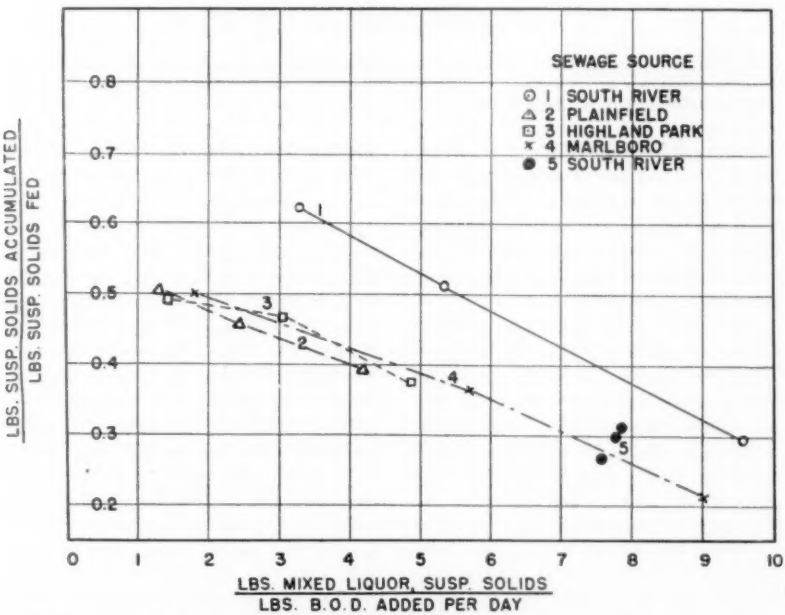

FIGURE 5.—Relationship between solids accumulation, expressed as lb. suspended solids per lb. of B.O.D. fed, and mixed liquor suspended solids, expressed as lb. per lb. of B.O.D. fed (sludge age on B.O.D. basis).

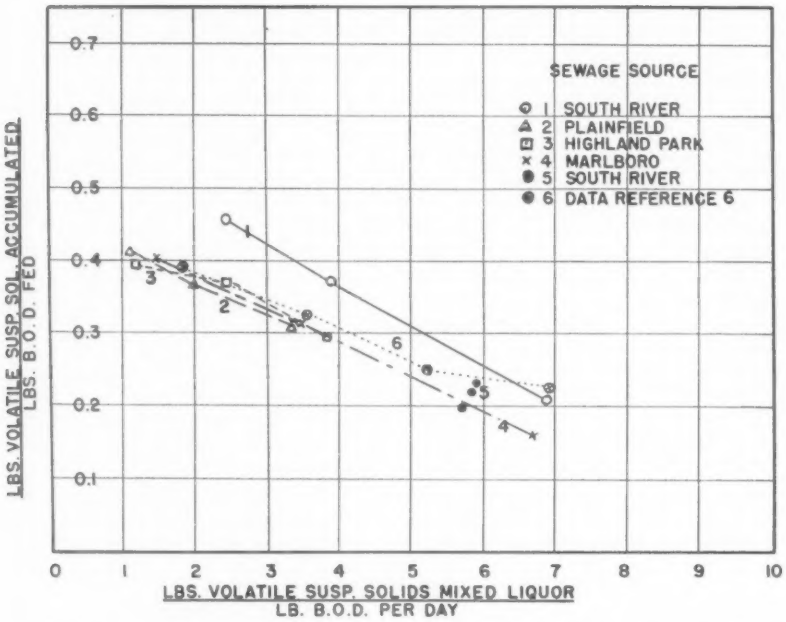

FIGURE 6.—Relationship between suspended solids accumulation, expressed as lb. volatile solids per lb. of B.O.D. fed, and mixed liquor suspended solids, expressed as lb. volatile solids per lb. of B.O.D. fed.

other experiments. In other words, when the sludge accumulation and mixed liquor suspended solids are related to B.O.D. of the sewage fed, discrepancies previously obtained between experiment No. 5 and the others are nearly eliminated.

An even better agreement between the five individual runs is obtained when the suspended solids accumulation is expressed on the basis of volatile solids per unit amount of B.O.D. fed and is compared with the volatile solids in the mixed liquor per unit amount of B.O.D. fed (Figure 6). Not only do the results from the present study show a definite regular relationship, but also results obtained by Sawyer (6) converted and adjusted to the same unit terms fall within the same range of values. Search for data from other sources for further confirmation was futile, because some pertinent information was always missing.

Discussion

The increase in the quantity of sludge in the activated sludge process is the result of a combination of the following influences: (a) incorporation in the floc of resistant, and unavailable organic materials (debris) from the sewage; (b) residual available and oxidizable organic material removed from the sewage and which, because of the shortness of sludge age, has not been fully oxidized but which could be oxidized further if longer periods of aeration were available; and (c) the increase in bacterial protoplasm resulting from the oxidation of the portion of the available food materials removed from the sewage. Not all the organic materials in

sewage are equally available as bacterial food. A portion is not available at all and the removal of organic materials from sewage by activated sludge is not dependent on their availability for bacterial food. All types of materials present in sewage, whether organic or inorganic, available or unavailable, are removed. Some unavailable organic materials are present; otherwise, the determination of the total organic materials in sewage could replace the indirect method of arriving at the amount of available organic material by the B.O.D. test, and the *L*-value would be equivalent to the total organic matter content.

There is a gradient of availability of the various food materials present in sewage. That not all of the available food materials removed from sewage are oxidized in the activated sludge process follows from the fact that the return sludge itself has a high oxygen demand. It does not serve any useful purpose to carry the oxidation of the sludge to completion; in fact, such an attempt would end in the destruction of the activated sludge process as we know it. It would result in an inert mass of material with little adsorptive capacity, producing a poorly clarified and purified effluent.

The production of large quantities of protoplasmic materials from the limited oxidation of the available food is obvious and can be detected readily by microscopic observation. The greater the amount of food oxidized, the greater is the contribution of growth to sludge accumulation and the lesser the contribution of the residual unoxidized organic material to sludge accumulation. The net increase in sludge accumulation would be the resultant of these two opposed forces.

The observed influence of suspended solids concentration of the mixed liquor on the accumulation of sludge illustrates these principles. With a given quantity of food (sewage treated) the increase in quantity of sludge formed is greater with lower suspended solids content in the mixed liquor. Granting that mixed liquor suspended solids concentration within a wide range does not affect the removals from sewage, because the effluents contain nearly the same amounts of impurities as measured by B.O.D. and suspended solids, the only influence affecting sludge build-up can be attributed to the relative amounts of oxidizable materials removed and the resultant growth. With low suspended solids in the mixed liquor, a given amount of organic material removed from sewage gives rise to a greater sludge accumulation because oxidation is limited by the disparity between the food and the number of organisms and limited oxidation would result in a relatively greater amount of biological growth. In other words, the relatively fewer organisms present under this condition multiply to a greater degree to carry on the limited oxidation and hence produce more growth and the sludge formed is higher in protoplasmic growth. When a higher suspended solids concentration is maintained in the mixed liquor there is not so much food per unit of organisms. As a result, the oxidation is carried on further, giving a smaller sludge accumulation, and the protoplasmic growth is relatively less because there are more organisms per unit amount of food and hence less multiplication per individual organism. In the former case, the sludge produced is not so fully oxidized and contains proportionally a greater amount of protoplasmic growth. It may be considered as an overgrowth of organisms as a result of disparity between organisms and food. The volatile solids content of the sludge should, therefore, decrease with increasing mixed liquor suspended solids concentrations, as is confirmed by the relationship shown in Figure 7. There is a small but significant decrease in the per cent volatile solids in the mixed

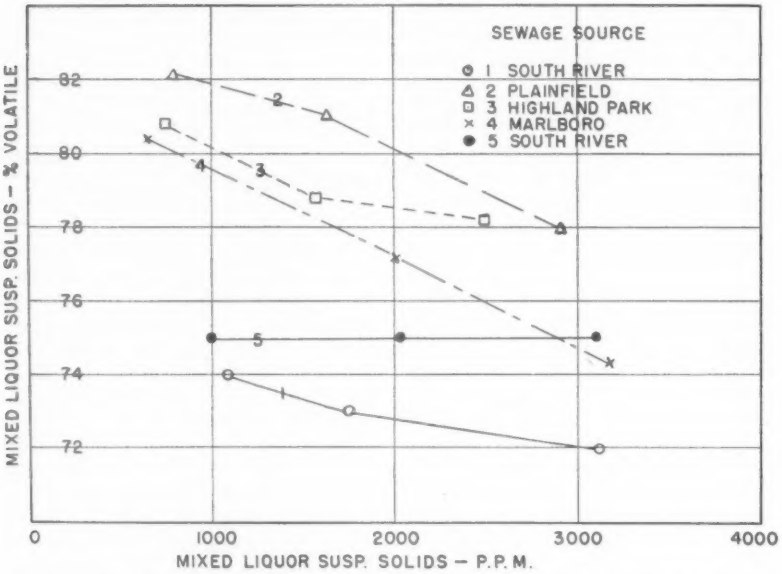

FIGURE 7.—Relationship between the percentage volatile solids in mixed liquor and mixed liquor suspended solids concentration.

liquor sludge with increasing mixed liquor suspended solids concentration in all the runs except No. 5, in which, significantly, the sewage was fed in direct proportion to the suspended concentration of mixed liquor, resulting in a constant sludge age. The fact that the volatile solids level in the different experiments is not the same is not so pertinent as the general decrease with increasing concentration. Another, perhaps more sensitive, parameter of the stage of oxidation, such as the oxidation-reduction potential, might have indicated even to a greater extent the effect of sludge concentration.

It is apparent from the results that however important is the mixed liquor suspended solids concentration to the quantity of sludge formed, it is not the only factor. One of the most illuminating illustrations of the importance of other factors is the result obtained from run 5, in which various suspended solids concentrations were maintained but the sewage was fed in proportion to the sludge concentration (the same sludge age was maintained). Under this condition the sludge accumulation did not decrease with increasing concentration of suspended solids in the mixed liquor. It follows that, in addition to the effect of sludge concentration *per se*, the relationship between sludge and food is an important factor. With a given sludge age, therefore, irrespective of sludge concentration, the same amount of sludge should be formed. That the generally accepted definition of sludge age is not the ultimate criterion is indicated by the lack of agreement between the different runs on the basis of the relationship between mixed liquor suspended solids and suspended solids in the sewage (Figure 3). The agreement between sludge accumulation and mixed liquor suspended solid concentration improved in increasing

order when the influence of the following factors was taken into consideration:

1. By evaluating the sludge accumulation in terms of suspended solids in the sewage fed (Figure 3).
2. By evaluating the sludge accumulation in terms of suspended solids in the sewage fed plus relating the mixed liquor concentration to the suspended solids in the sewage fed (sludge age) (Figure 4).
3. By evaluating the sludge accumulation in terms of B.O.D. in the sewage fed and the quantity of sludge in the mixed liquor in relation to the B.O.D. of the sewage fed (sludge age in terms of B.O.D.) (Figure 5).
4. By placing the relationship on the basis of volatile solids accumulated in relation to the B.O.D. fed and the quantity of sludge in the mixed liquor in terms of volatile solids as related to the B.O.D. fed (Figure 6).

It appears that sludge accumulation from normal domestic sewage is more a function of the B.O.D. than of the suspended solids of the sewage. It follows that solids, as such, do not exert so much influence on sludge build-up as does the oxidizable matter, that the incorporation of solids in the floc is not so great a contributing factor in the sludge build-up as is the oxidizable matter, and that the incorporation of solids in the floc is not so great a contributing factor in the sludge build-up as are the utilization and the oxidation of oxidizable organic matter in sewage. With a constant ratio of B.O.D. to suspended solids in the sewage treated, suspended solids might be taken as a measure of quantity of sludge build-up; but with a variation of this ratio, the B.O.D. of the sewage is a better index. The ratio may vary in domestic sewage from time to time, and from place to place, and more decidedly in the presence of industrial wastes. In the treatment of soluble organic industrial wastes the concept of sludge age on the basis of suspended solids in the waste becomes meaningless. Furthermore, in the ultimate evaluation of sludge build-up, even in terms of B.O.D. fed, it is more significant to base it on the volatile solids of the accumulated sludge than on the basis of total solids.

The evaluation of sludge accumulation is also best expressed on the basis of volatile suspended solids in the mixed liquor in relation to the B.O.D. fed.

The quantity of sludge formed can be evaluated on the basis of the curve presented in Figure 5 and, where A is lb. of volatile suspended solids accumulated per day, S is lb. of volatile mixed liquor suspended solids, and B is lb. of B.O.D. fed per day, can be mathematically predicted as follows:

$$A = -0.055\ S + 0.5\ B.$$

On the basis of experimental results, the accumulation has varied from a minimum of 304 to a maximum of 1,268 lb. per m.g. Imhoff and Fair (3) give a value of 854 lb. of dry solids per m.g. Between this value and the present experimental minimum and maximum values are arrayed all the influences of mixed liquor concentration, sewage strength, ratio of B.O.D. to suspended solids of the sewage, etc., discussed above.

It is difficult to refrain from speculating on the relationship of these observations to sludge bulking. The rate of sludge build-up and sludge bulking must bear some relationship to each other. Factors such as sludge concentration in mixed liquor, sewage strength, relationship between load (suspended solids and/or B.O.D.) and suspended solids in mixed liquor, which affect the rate of sludge build-up, also affect the sludge bulking. When the quantity of solids carried in the activated sludge process is low in relation to the amount of food to be handled, sludge accumulation, depres-

sion of the oxidation, stimulation of excessive growth, and sludge bulking are greater. Sludge bulking in this sense has its parallel in the clogging of trickling filters. It can further be postulated that protoplasmic organic material in the activated sludge has a higher volatile matter content, a higher moisture content, and a lower specific gravity than the non-living organic matter in the floc. The availability of the food, as manifested by a relatively high B.O.D., in relation to suspended solids causes a greater rate of protoplasmic growth and more sludge bulking, as manifested ultimately by the bulking caused by sugars. Dispersed cell growth (1) may be looked upon as the ultimate in bulking where there is no aggregation of cells into floc.

The influence of air supply in these complex relationships cannot be overlooked. As the sludge becomes less oxidized as a result of improper balance between the food (sewage strength in terms of B.O.D. and/or suspended solids) and the organisms (suspended solids in mixed liquor), it exerts a greater oxygen demand, which may not be satisfied by the normal supply of air.

The simple straight line sludge accumulation relationship resulting from widely varying activated sludges and sewages suggests that the same factors might be used for routine plant control. A simple sludge loading factor based on the ratio of lb. of volatile mixed liquor solids per lb. of B.O.D. fed might be used for all activated sludge treatment.

A similar factor, sludge age, based on suspended solids, has been used to control the activated sludge process. Mallory (5) has used a complicated formula involving these and other factors for control. Possibly, a single loading range based on the lb. of volatile mixed liquor suspended solids per lb. of B.O.D. fed per day could be established to control the regular activated sludge treatment. Possibly, also, such a loading factor might provide a sharper distinction between the modified activated sludge and the normal activated sludge processes.

It is also possible that the air required to maintain a particular loading factor can be established so that the mixed liquor solids, sewage, B.O.D., and air volume can all be evaluated in one or two simple formulas.

The experiments were all performed at room temperature (19° to 22° C.) The relationships established by these experiments hold for this temperature range. It is believed that temperature changes would follow the usual temperature effect trend and would not affect the straight line relationship of volatile sludge solids accumulation, but would affect both the slope of the line and the y-axis intercept. Since temperature affects biological processes by some exponential relationship, a general formula for activated sludge organic suspended solids accumulation might have the following form:

$$A = -M^{kt} S + F^{kt} B$$

in which A is the lb. of suspended solids accumulated per day; S is the lb. of volatile mixed liquor suspended solids; B is the lb. B.O.D. fed per day; M, k, and F are constant; and t is temperature.

Since, for any given temperature, M^{kt} and F^{kt} would also be constants, the curve would be a straight line when plotted on rectangular coordinates. The slope of the line would be $-M^{kt}$ and the y-axis intercept would be F^{kt} (lb. B.O.D. per day). For different temperatures these curves would plot as a family of straight lines, each line representing a different operating temperature.

On a practical basis, irrespective of the possible implications of the relationship between sludge accumulation and sludge bulking as a function of sludge concentration, sludge age, and load factors, sludge accumulation *per se* has an important bearing on sludge

disposal. The differences in the quantity of sludge accumulation with different sludge ages (on the B.O.D. basis, Figure 6) are significant from the standpoint of disposal. With 1-day sludge age, 0.4 lb. of volatile solids is obtained per lb. of B.O.D. fed, whereas with 8-day sludge age, 0.1 lb. of volatile solids is obtained on the same basis. It would seem that a greater sludge age period might prove advantageous from the standpoint of sludge disposal by digestion and filtration because, in addition to the effect of sludge age on sludge volume (bulking of solids), smaller quantities of sewage will be produced. On the other hand, when activated sludge is to be converted to fertilizer, a lower sludge age might be desired.

Conclusions

Five batch activated sludge experiments were run with three daily dosings of sewage for a period of 10 days each at three different suspended solids concentrations. A careful solids balance revealed the following:

1. The suspended solids accumulated decreased with increasing mixed liquor suspended solids, when a given sewage was fed.
2. With given mixed liquor suspended solids concentrations, the amount of sludge accumulated varied with different sewages.
3. When the sludge accumulation was expressed on the basis of a unit amount of suspended solids fed, the variations between different sewages decreased somewhat.
4. The results from the different experiments were closer when sludge accumulation was related to the B.O.D. fed.
5. Ultimate agreement was obtained when sludge accumulation was expressed in terms of volatile solids per unit amount of B.O.D. fed *versus* volatile mixed liquor suspended solids per unit amount of B.O.D. fed.
6. The expression of sludge age on the basis of volatile solids in the mixed liquor in relation to B.O.D. fed corresponds more closely to the observed facts than the sludge age as usually defined (as the relation between mixed liquor solids to suspended solids fed).
7. Sludge accumulation in these experiments varied from a minimum of 304 to a maximum of 1,268 lb. per m.g. of sewage treated, depending upon the mixed liquor suspended solids and sewage strength.
8. The sludge accumulation may be evaluated by the following formula (for 20° C., approx.):

$$A = -0.055\ S + 0.5\ B$$

in which A is the lb. of volatile suspended solids accumulation per day, S is the lb. of volatile mixed liquor suspended solids, and B is the lb. of B.O.D. fed per day.

9. Sludge accumulation is influenced by mixed liquor concentration; sewage strength in terms of B.O.D. or suspended solids, or both; and the relationship between sewage strength and mixed liquor concentration.
10. The factors that induce greater sludge accumulation also induce bulking.
11. For a given sludge age

$$\left(\frac{\text{vol. susp. sol. in mixed liquor}}{\text{lb. B.O.D. fed}}\right),$$

the sludge accumulation is the same irrespective of mixed liquor suspended solids concentration.

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TENTATIVE STANDARDS FOR SEWAGE WORKS REVISED

Under date of January, 1951, a revised version of "Tentative Standards for Sewage Works" is available on a limited basis for use by consulting engineers and other interested parties. The report is an outgrowth of constructive criticism of a preliminary draft (see THIS JOURNAL, **22**, 1, 40; Jan., 1950) and was compiled by a joint Committee on Development of Uniform Standards for Sewage Works, representing the Upper Mississippi River Board of Public Health Engineers and the Great Lakes Board of Public Health Engineers. The "Standards" are intended to eliminate present confusion encountered by consulting and designing engineers practicing in the several states represented.

The 10 states represented in one or both of the two Boards are Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin. Each of the 10 State Departments of Health has about 200 copies of the "Standards" for distribution within its own state. A further limited supply is available for pertinent distribution to persons and agencies outside the 10-state group through John M. Fairall, Public Health Engineer, Environmental Sanitation Section, Wisconsin Board of Health, State Office Building, Madison 2, Wisconsin.

FUNDAMENTALS OF SEWAGE PUMPING *

By Glenn E. Hands

Burns & McDonnell Engineering Company, Kansas City, Mo.

The problem of sewage pumping has been discussed in many papers, each emphasizing a different phase of the problem. This is understandable, because the subject is too broad for adequate coverage in a single paper. For that reason and because some very recent papers have been presented which cover many points and features of design, this paper is confined to a discussion of the unattended, automatic, electric-powered lift station for the handling of sanitary sewage.

Wet-Pit Installations

Wet-well stations with submersible pumps are economical to construct, but have inherent shortcomings, which become increasingly evident to the owner and operators as the installations age and deteriorate. Among the factors that must be considered are:

1. The explosion hazard. The sewer gases have free access to the room in which the electric motors and their circuit breakers operate.
2. The lethal gas hazard. Poisonous and lethal gases can accumulate in the room where the units must be serviced and maintained.
3. The extra and excessive maintenance required. Submersible pumps require more maintenance than dry-pit units.
4. The extra difficulties of maintenance. A clogged pump must be lifted out of the wet well for inspection and/or repair.

Many health authorities will permit wet-well stations only within industrial establishments or where the number of houses served is 50 or less. It is believed that if it were not for the advantage of their low construction cost, they would be ruled out without exception. Of course, by proper design many of the hazards can be reduced. For example, explosion-proof wiring, motors, and fixtures may be used. Forced air fans may be installed. The wet well may be vented with exhaust fans. Hoists may be installed for easy removal of the pumps. Despite all of these safeguards, however, the hazards and inconvenience of the wet-well design are still present. Imagine, for example, the effect of a gas main break where its contents can flow into the sewer; or consider the effects of a truck load of gasoline poured into the system as the result of an accident. With a wet-well installation a second accident may occur before one can do a thing about it. The records reveal many similar cases.

Dry-Pit Installations

The dry-pit installation permits a complete separation of the wet well from the room and pit in which the equipment is installed. Hazards are reduced and convenience for maintenance and operation is improved.

Where equipment can be reached readily and seen clearly, it is maintained better. To this end the dry pit sould be constructed with enough room to permit easy access to and working space around the pumps, valves, and other equipment. It should not be necessary to duck around or crawl under piping, brackets, etc. A stairway or circular stairway is preferable to manhole steps or a steel ladder as a means of access to the pit. Ample lighting should be provided. A trolley

* Presented at 1950 Annual Meeting, Missouri Water and Sewerage Conference; St. Louis, Mo.; October 1–3, 1950.

hoist rail and hatchway should be provided to facilitate the removal and replacement of pumps and equipment.

Check valves should be located where they can be opened and inspected without undue inconvenience. A hose bib should be provided in the dry pit so that the floor and walls can be washed down after a pump or check valve is cleaned.

Gate valves have been widely used as the shut-off valves on each side of the pump, but they have also been responsible for some of the stoppages in sewage lift stations and are sometimes difficult to close tightly if a stone or rag becomes lodged in the seating area. Lubricated plug valves are a little more expensive in the larger sizes, but are much more satisfactory in operation. They are recommended as preferable to gate valves for all sewage installations. The hydraulic characteristics of a plug valve are better than those of a gate valve, as friction losses are less.

Check valves tend to cause water hammer and create high friction losses in the discharge piping. Both of these conditions are more severe at high velocities, increasing approximately as the square of the velocity. Generally, the discharge velocities at the pump outlet are very high, ranging in many cases from 15 to 20 ft. per sec. In these cases, the line size should be increased ahead of the check valve installation so that the velocity through the check valve is between 8 and 12 ft. per sec. Horizontal swing check valves seem to clog less than vertical checks and can be cleaned more easily. The valve industry should try to develop a better check valve for sewage than the present swing check. It should be more readily accessible, with perhaps a lighter cover, fewer tie-down bolts, wing nuts instead of hexagonal nuts, and an exterior indicator that will show when the valve is not seating properly.

Even with the complete separation of the wet well from the pump pit, there remains the threat of possible gas accumulations in the pit. Some of the poisonous and explosive sewage gases are heavier than air. Their removal from the dry pit must be assured by the installation of an exhaust fan with its inlet near the floor of the pit. The ventilation equipment should have a minimum capacity of 6 turnovers per hour under continuous operation. With intermittent operation a 2- to 3-min. turnover should be provided. Others of the poisonous and explosive gases are lighter than air. Pockets where light gases may accumulate must be well ventilated.

The Wet Well

The wet well should be completely separated from the dry pit and motor room. That is, there should be no openings between the two that are not watertight and practically gastight. Each should have a separate outdoor entrance and each should be ventilated separately.

By far, the majority of the lift stations are not equipped with screens of any kind. For small stations, where screens are most needed, their installation is too costly for the average designer, who is trying to spread his dollars as far as he can. In the larger stations, where screens can be afforded, their need is thought to be not so urgent because the larger pumps pass larger solids with fewer stoppages.

There is also the problem of keeping the screens clean. If mechanical screens or comminutors are not furnished the screens must be hand cleaned. Manually cleaned screens should be accompanied by the following design features:

1. Bar screens placed at approximately 45 degree angle with the vertical, with clear spacing of 1.5 to 3 in. between the bars.
2. A total screen area below the crown of the sewer at least six times the area of the inlet pipe.

3. A drain platform, upon which the screenings can be raked.
4. A stairway to the platform; not manhole steps.
5. A superstructure above the ground line over the wet well.
6. Adequate ventilation. It is advisable to provide a fresh air inlet and fan, which will blow upon the operator as he works at the platform. The fan should provide for a complete change of air every 2 to 3 min. and be connected with the light switches. The operator should be warned not to enter the well too hastily. A relay can be connected to the switch so as to delay the light energization for 1 to 2 min.
7. Adequate light on the screens, stairs, platform, and wet-well walls for safety.
8. Explosion-proof electric switches, fixtures, and motors.
9. A container and hoist for removal of the screenings.

These requirements may appear to be excessive and expensive, but unless they are included, neglect will surely follow. It may be better not to install screens if the screen cleaning operation is made difficult and hazardous.

Pneumatic ejectors, "Flush Kleen" pumps, or so-called bladeless pumps, if used, may reduce the number of outages otherwise experienced, but they are not a substitute for adequate screening. A pair of overalls may pass through a pump, but catch on the check valve, causing backflow when the pumps are off and excessive head losses when on. Stones may pass through the pump, but not without some wear and damage to the pump. Waterlogged 2 × 4's can lodge in the suction lines, and stringy fibrous material can wind about the impeller shaft. Screens or comminutors will eliminate most of these difficulties.

If odor nuisances of the lift station are to be considered, the wet well should not be made so large that the sewage at low flows will stand long enough to become septic.

Some public health authorities require that the wet well be of such size that at average flows the pumps will not remain idle for more than 10 min.; others permit 15 min. at design flows.

The side walls should be made accessible for frequent cleaning and scraping. Water should be available for washing down the walls, but possible cross connections to the public water supply must be avoided. The floor of the wet well should slope toward the suction pipes of the pumps at approximately 45 degrees so that most of the settled material will be removed with each drawdown.

Sewage Lifting Equipment

For the automatic station, sewage is generally lifted by electric power through either centrifugal pumps or pneumatic ejectors.

The pneumatic ejector is one of the oldest and most successful types of lifting equipment on the market. It is limited, however, to sewage lifts of 50 ft. or less, because of the freezing effect of the air released at higher pressures. In capacities greater than 500 g.p.m. it is out of competition with the non-clogging sewage pumps, due to its relative operating inefficiency. The noise of the unit may be sufficient to reject its use at some locations.

The non-clogging sewage pump is not non-clogging, but is considerably less likely to clog than its counterpart for pumping clear water. To accomplish this relatively trouble-free service, the sewage pump is designed with large rounded openings, repelling vanes, and special bearing packing assemblies that tend to resist the wear and grinding effects of grit and sand.

Grit damage can be reduced by the use of such special features as spring-loaded grease cups, pressure grease fittings, or a clear-water supply under pressure applied against the packing glands in a manner to keep the grit

out. Some pump manufacturers consider grease perfectly satisfactory for the smaller pumps. Others discourage their use and favor the use of water under pressure. A special packing material must be used with grease on some pumps, whereas, if water is used, ordinary packing materials are just as satisfactory.

If water is used to wash grit out of the packing glands, it must not be connected to the city supply. However, in order to function properly, the pressure must be greater than the sewage pump discharge pressure. Usually a small, packaged, water system of the type furnished to farmers by the mail-order houses is quite satisfactory. A tank with a float-controlled valve from the city supply completes the installation. A considerable amount of water will be saved if a solenoid valve is installed in the clean-water line to each sewage pump in such a way as to shut off the clean-water supply when the pump shuts off. An alternate installation, which does not require a pressure tank, can be made with a small turbine-type pump interlocked with the sewage pumping equipment so that the turbine pump operates only when the sewage pump is operating.

In general, the most troublesome pumps are the smaller ones, especially those less than 6 in. in size. It is now generally recognized that pumps with inlet and outlet diameters less than 4 in. should not be used for pumping municipal sewage. The pump should be capable of passing solids at least 2½ in. in diameter. This limitation creates another problem. Pumps of 4-in. size have a minimum capacity which is far in excess of the requirements of many lift stations. One manufacturer's lowest capacity 4-in. pump is approximately 200 g.p.m. at 20-ft. head. Not many 4-in. pumps are available with capacities below 250 g.p.m. Thus, for very small stations, it is difficult to find a conventional sewage pump small enough for the job.

For the smaller stations, where the proper capacity of conventional trash pumps would be too small for reasonably reliable service, there are two special pumps on the market; namely the "Flush Kleen" pump and the "bladeless" impeller pump.

The "Flush Kleen" sewage ejector is fundamentally a special combination of two conventional sewage pumps. They are combined in such a way with special built-in screens or strainers that only screened sewage passes through the pump. These units are furnished in capacities from 50 g.p.m. and 12-ft. head up to almost any capacity and head normally encountered.

The "bladeless" impeller pump is actually a single-bladed pump. The casing and all of the working parts of a "bladeless" pump are exactly the same as a conventional trash pump. The only difference is in the impeller. In fact, in a conventional trash pump made by the manufacturers of the "bladeless" pumps, the conventional impeller can be exchanged for a "bladeless" one. With the substituted impeller, the pump will deliver approximately one-half the rate of flow of the former impeller, the efficiency will be off five to seven points, and the required motor horsepower will be a little more than one-half that originally required. On the other hand the "bladeless" pump is said to be 10 to 25 times as hard to clog as its conventional counterpart. "Bladeless" pumps are furnished in 2-in. to 5-in. sizes and in capacities from 30 g.p.m. at 10-ft. head to 1,100 g.p.m. at 65-ft. head, or 450 g.p.m. at 130-ft. head. Larger pumps may soon be available.

How Many Pumps?

Sewage lift stations must be designed to deliver the maximum flow entering the station. If only one pump were installed, it would have to deliver that maximum rate. However, for reliability at least two pumps are usually required. Some engineers con-

tend that each pump should at least equal the maximum flow. Thus "firm" capacity is assured at all times, even though one of the pumps may become burned out or clogged up during the period of peak flow. Others say that each pump capacity should at least equal the average flow into the station and that the total capacity of the plant should slightly exceed the maximum flow. Proper maintenance should reduce to a negligible factor the probability of failure during peak flows.

Figure 1 indicates a typical load duration curve for sewage flow. The peak flows are 3.5 times the average flow in this curve. In some communities the peaks are as much as 5 to 6 times the average flow; in others, as low as 2.5 times the average. However, assuming Figure 1 to be typical, it will be noted that the average flow and less occurs 70 per cent of the time, and that flows in excess of double the average occur less than 10 per cent of the time. Flows in excess of three times the average occur less than 2 per cent of the time.

If only one pump (or two duplicate pumps each equal to the maximum flow) is furnished, the pump and connecting piping will have to be very large compared to the average usage. Power costs may be high because the power demand will be high every time the pump operates. The number of pumps to be installed becomes an economic problem. Perhaps two, three, or even four or five, may be justified, depending upon several other related factors discussed in the following.

An illustrative example is carried through the remainder of this paper. The scale on the left side of Figure 1 provides the basic assumption of an average flow of 500 g.p.m. This flow might be expected from a community of 10,000 to 15,000. The maximum flow is 1,700 g.p.m.

Hydraulic Considerations

Sewage lift stations are called upon to lift sewage under three types of hydraulic conditions, as follows:

Type I—Lifting the sewage from a lower to a higher elevation, where it

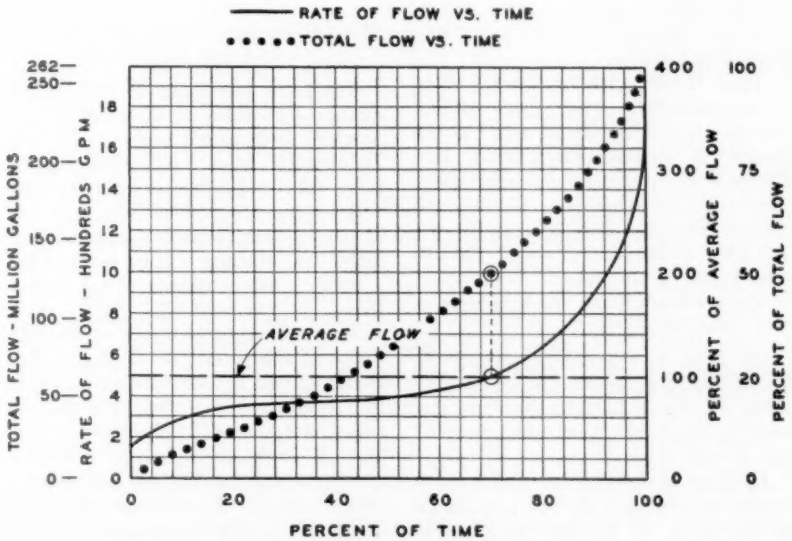

FIGURE 1.—Typical load duration curve for sewage flow.

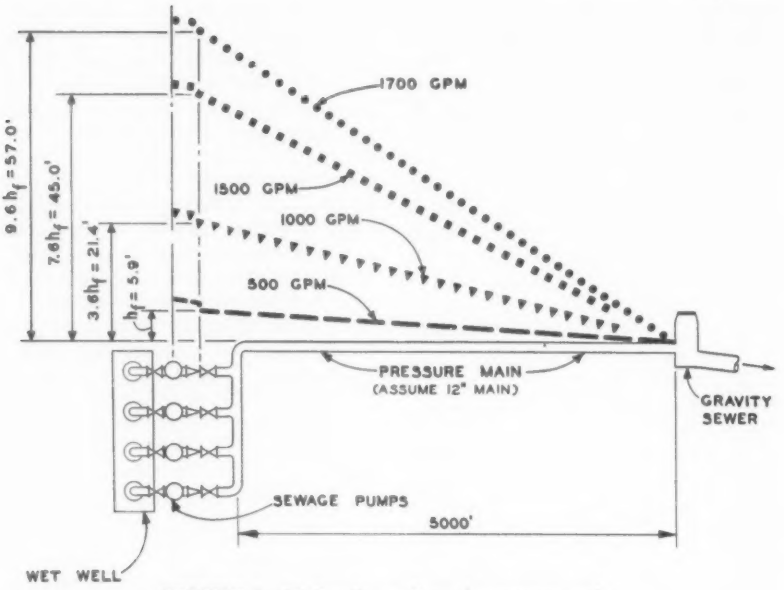

FIGURE 2.—Hydraulic gradients in pressure main.

discharges freely into a gravity sewer. Here the pumps must be designed to deliver against the static head primarily, plus a small amount of friction head through the inlet and outlet piping and valves.

Type II—Pushing the sewage along in a substantially level, closed conduit. In this case the pumps must be designed to deliver the desired flow through the pressure main against the friction of the main pipe, plus a small amount of static head between the water level of the wet well and the discharge end of the pipe.

Type III—Infinite combinations of the other two.

In Type I, the discharge main is short and the operation of two or three pumps in parallel does not materially affect the head conditions of the system.

In Type II, however, as the flow increases, so also does the head, as shown in Figure 2. If the flow through the pipeline is doubled, the friction loss increases 3.6 times; if the flow is tripled, the head loss due to friction increases 7.6 times.

Head-Capacity Curves—Pumps and Force Main

The same principle might be expressed differently as shown in Figure 3, which is a specific example of 5,000 ft. of 12-in. pipe. When the pipe is new, its head-capacity characteristic follows the lower curve; as it grows older (becomes corroded and tuberculated), its capacity will be reduced for a given head as shown in the upper line.

A centrifugal pump has an entirely different characteristic. Pump B, for example, will deliver 630 g.p.m. when the pipeline is new, but will deliver only 570 g.p.m. as the pipe grows older. This is sufficient to carry one-third of the maximum flow of the station. Thus, it might be reasoned that two additional pumps of the same capacity would be adequate. Nevertheless, as

the flow through the pipe increases, the head also increases, until at 780 g.p.m. the total required pumping head is increased to 33 ft. At this head, pump B would deliver only 390 g.p.m. Thus, if two of these pumps were operated together, their combined capacity would be only 780 g.p.m., due to the extra friction loss in the pipeline. Three pumps of like characteristics will deliver only 870 g.p.m. Yet the one pump delivered one-third the maximum designed flow of the station.

Then it may be reasoned that the pump was selected incorrectly, that each pump should have been selected at the maximum head, 77 ft. If three pumps are desired, each should be purchased for delivering 570 g.p.m. at 77-ft. head. When one of these pumps operates alone it delivers, not 570 g.p.m., but more than 1,000 g.p.m. An inspection of the load duration curve (Figure 1) reveals that the one pump of this characteristic will operate 92 per cent of the time and every gallon of water will have to be pumped at 42 ft. of head, instead of at the 27-ft. head required at 570 g.p.m.

However, another important consideration is the efficiency of the pump. Usually the specifications require that the pumps operate at their maximum efficiency at or near their designed head-capacity point. It would be better in this case to specify a pump which operated at its peak efficiency at almost double its design capacity. The head-capacity and efficiency curves shown in Figure 3 represent the most satisfactory pump selection available by one manufacturer. It should be noted that the maximum efficiency of 69 per cent is beyond the design capacity point, but that the curve drops off rapidly to only 55 per cent at the point where the pumps will be operating 92 per cent of the time, delivering approximately 80 per cent of the total water pumped during the year.

The problem becomes one of comparing total costs, including fixed and operating costs, of several pump combinations. This has been done assuming that power can be purchased at 1.5¢ per kw.-hr. and that the municipality can finance improvements at 3 per cent interest on 20-year bonds,

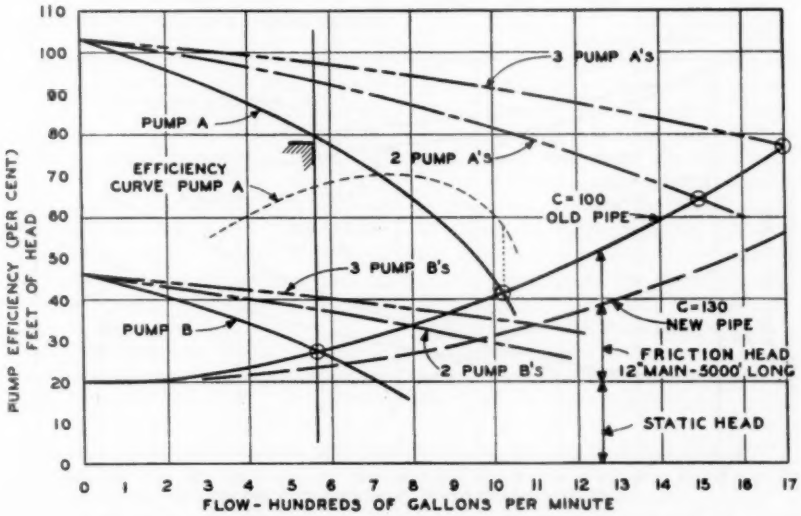

FIGURE 3.—Head-capacity curves for pumps and 12-in. force main.

which is also a reasonable life for the plant and equipment.

The following plans were considered:

Plan No.	Installed Pumps			Annual Power Cost ($)
	No.	Cap. (g.p.m.)	Head (ft.)	
I	3	570	77	1,130
II	1	570	27	
	2	850	77	970
III	1	570	27	
	3	570	77	870
IV	1	570	27	
	1	1,000	42	
	1	1,700	77	830
V	2	850	77	1,500

Construction costs reduced to annual costs vary as follows:

Plan No.	Estimated Construction Cost ($)	Annual Fixed Charges ($)	Annual Power Cost ($)	Total Annual Cost ($)
I	27,000	1,800	1,130	2,930
II	26,400	1,770	970	2,740
III	33,000	2,200	870	3,070
IV	30,000	2,000	830	2,830
V	22,000	1,470	1,500	2,970

In this case, plan II (see Figure 4) is the most economical plan to construct and operate, even though plan IV does require less power and plan V is cheaper to construct. Plan II provides for one pump to operate at average flows and two large pumps, which, when operating together, pump at the maximum rate of flow, and a spare equal in capacity to the larger pumps. Of course, pump "B" becomes the work horse and has little time off. It will wear more than the other pumps; when it does go out, it should be repaired as quickly as possible. It is a money saver to the purchaser, because it operates most of the time and is selected to operate at its peak efficiency at all times.

The small pump must be interlocked with the larger pumps in such a manner that it cannot be operated while either of the larger pumps is in operation.

Selection of the proper pumps for a lift station is not a simple task. Unless the problem is fully understood and all of the factors duly considered, the station may fail to operate as expected or may operate very inefficiently, using up precious dollars that

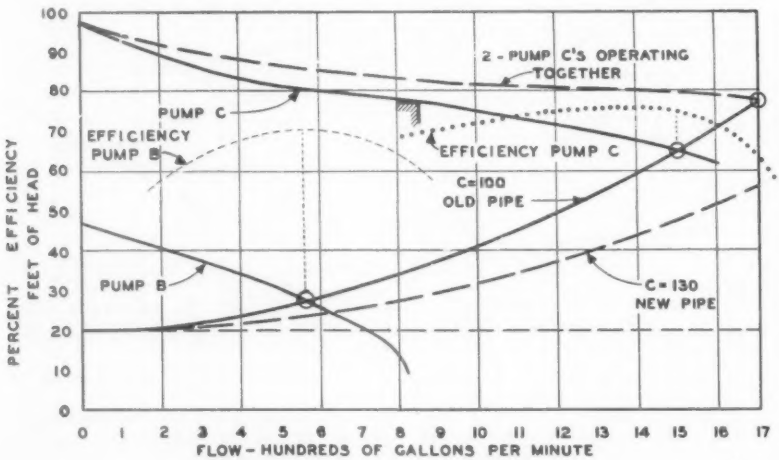

FIGURE 4.—Pump selection for plan II.

may well be spent for more useful services.

Designer's Tips to Operators

A designer is always learning from operators many valuable pointers in design, for the operators are the ones who live with the plant and know its faults and its points of merit. Conversely, designers occasionally may be able to give an operator a tip.

For example, some test data on a sewage lift station were received not long ago. The pumps discharged into a pipeline 5 mi. long. The operator tested the capacity of the station by shutting off the inflow into the wet well and timing its evacuation by the pumps. Knowing the wet-well volume and catching the time of shutoff of each pump, he did a very good job of estimating the rate of flow from three pumps operating together, then two pumps, and finally one pump. All pumps were supposed to be of the same capacity.

The test results showed that one pump delivered 820 g.p.m., two pumps delivered 2,590 g.p.m., and three pumps delivered 5,550 g.p.m. A fourth pump was idle. It was possible to show the operator that he had check valve trouble, a discovery which is saving the city more than 30 per cent on that particular station's power bill. This fact was confirmed by an analysis of the electric bills, which revealed that the power consumed per million gallons of sewage pumped was greatest during the months of least flow. The opposite would have been expected. The backflow through the damaged check valves accounted for the apparent paradox.

An efficiency test of the pumps in another lift station indicated operating efficiencies below 45 per cent on two of three pumps, although according to the manufacturer's curves, the efficiency should have been 65 per cent at the rate the pumps were operating. The third pump tested 70 per cent, as compared to a rating of 71 per cent. Inspection of the impellers, rings, and sleeves revealed the trouble. The repair of these pumps saved that city almost $1,000 per year on its power bill.

Check valves are an essential part of most lift stations, especially those where the pumps operate primarily against a large friction head (discharge through a long force main). They are also a source of considerable trouble, because of their shape and operation. Materials are bound to get caught on them, restricting the flow of sewage and preventing a tight shutoff. The most serious part of the check valve trouble lies in the fact that it may be stuck partially open without the knowledge of the operator, unless he is conscientious enough to remove the lid and inspect the flap and seat regularly, or unless he has noted an otherwise unaccounted for increase in the power consumed at that station.

An existing pumping station that fails to meet the minimum standards suggested herein usually can be modified and improved so that the most glaring deficiencies are eliminated. In the interests of health and safety these corrections should be made. Pumping stations are too often treated as the stepchildren of the sewage system by designers and operators alike. They are the unwanted part of the family and, therefore, are often neglected. This situation should not exist. Lift stations provide the saving grace of otherwise hopeless situations. Where an alternate is possible, its cost is usually many times the cost of the station and its power and maintenance requirements. It would be well if a small part of this saving could be set aside to make the station the most carefully designed, constructed, maintained, and operated part of the entire system. In that way it will continue to pass marvelous dividends to the owner and operator.

DETERMINATION OF CHLORINE DEMANDS AND CHLORINE RESIDUALS IN SEWAGE

By Isadore Nusbaum and Lawrence A. Meyerson

Supervising Sanitary Chemist and Senior Sanitary Chemist, respectively, Sewage Treatment Plant, Detroit, Mich.

PART I. CHLORINE DEMANDS

The determination of chlorine demands and chlorine residuals in raw sewage and primary treatment effluents has long presented a serious problem in the adequate control of sewage chlorination. The ortho-tolidine and neutral starch-iodide tests for chlorine residuals and demands in sewage, as given in "Standard Methods" (1), were originally used in water analysis, wherein minimal concentrations of physical and chemical interferences were present. Those familiar with the use of the above tests in sewage have encountered the anomalies which make the results of the determinations bear vague resemblance to any possible preciseness.

The chlorine-active substances found in sewage following the addition of nominal doses of chlorine are a mixture of chloramines. Free chlorine is never found in raw sewage or primary treatment effluent as a result of normal sewage chlorination practice. However, an effort was made to demonstrate the presence of free chlorine in sewage immediately following the addition of chlorine in amounts in excess of the chlorine demand determined by conventional methods. The ortho-tolidine flash test and the para-aminodimethylaniline flash test were used with little success. A modification of the benzidine-pyridine reaction with cyanogen chloride was used to detect free chlorine. This reaction is specific for free chlorine or bromine. No free chlorine was found in the sewage by this method. The conversion to chloramines is almost instantaneous and confirms in part the results obtained by Butterfield and Wattie (2) on the preparation of chloramine solutions. In effect, the momentary presence of free chlorine in sewage is not responsible for the beneficial bactericidal results of sewage chlorination; the substances of prime importance which must be detected and determined are the organic and inorganic chloramines.

As has been pointed out by Marks *et al.* (3)(4)(5), it is impossible to determine with any degree of exactitude the chlorine residuals in sewage by the use of the standard ortho-tolidine reagent. The ortho-tolidine reagent reacts slowly with chloramines, particularly with organic chloramines. When the combined chlorine residuals are present in small amounts, the color development by some of the active compounds may be so slow that the color developed by the more quickly responsive chloramines may have long since faded. The presence of turbidity and the many industrial wastes found in the sewage of the modern urban area seriously interfere with the standard ortho-tolidine test. More than 150 comparative chlorine demand tests were made by the "series increment" method, using several indicators, including neutral starch-iodide and acid ortho-tolidine. For the sake of ease and simplicity the tests were made by a spot plate method, which in the case of the ortho-tolidine was essentially the BIL (Bird Island Laboratory) chlorine demand test (6) developed by the laboratory of the Buffalo, N. Y., sewage treatment plant. In more than 60 per cent

of the tests the ortho-tolidine chlorine demand was beyond the range of the series established. The average of the acid ortho-tolidine tests which were within the range was greater than that of any of the other indicators used, and in no case was the result of an individual ortho-tolidine test less than that of the other indicators used.

The neutral starch-iodide test, although less subject to interference by turbidity and chemical agents than acid ortho-tolidine, has one major difficulty. The iodine released by the addition of starch-iodide reagent to chlorinated sewage reacts or is absorbed almost immediately by many components of sewage, leading to high demands or low indicated residuals.

Marks *et al.* (3)(4), in an effort to indicate the true active combined chlorine residual in sewage, carefully demonstrated the magnitude of the resulting errors in the standard ortho-tolidine and neutral starch-iodide tests. They also showed, in both the amperometric and colorimetric phenylarseneoxide tests for chlorine residuals, that free iodine will not react in an acid medium with the materials that cause false tests in the neutral pH range. It was noted by Marks that the acid starch-iodide test, which might presumably give analogous results to the phenylarseneoxide test, was extremely variable and had long since been abandoned in favor of the neutral starch-iodide test. In the conventional acid starch-iodide test the acidification normally follows the addition of the starch-iodide. This technique does not correct the objection to the neutral starch-iodide test previously noted.

If the acid is added to the chlorinated sewage prior to the addition of the starch-iodide reagent, one of the actions that presumably takes place is the conversion of the chloramines to a more active form, and the chlorine residual changes markedly.

It was decided, however, to include the acid starch-iodide test for comparison purposes in the chlorine demand indicator investigation, but to use ortho-phosphoric acid for acidification, to minimize possible interference. In establishing a procedure to be used on a spot plate for the acid starch-iodide test, one drop of 10 per cent phosphoric acid plus two to three drops of starch-iodide reagent were premixed in a spot plate concavity prior to the addition of 1 ml. of the chlorinated sewage. On the addition of the sewage, the stable blue color of the iodine-iodide-starch complex formed immediately.

An investigation of the spot plate technique of premixing the acid and starch-iodide reagent was made; the results of chlorine demands determined by this method compared favorably with those determined using a para-aminodimethylaniline reagent plus potassium iodide test for chloramines. Marks *et al.* (3) found that the results obtained in a series of chlorine residual tests on sewage, using p-aminodimethylaniline plus potassium iodide, were comparable in value to those obtained by the phenylarseneoxide method. The premixing of acid and starch-iodide reagent was applied to the determination of chlorine residuals in a sample of chlorinated sewage. A stable, blue, iodine complex is immediately formed, which can be titrated readily with standard thiosulfate solution. The chlorine residuals in a number of samples were determined, using the modified acid starch-iodine method in parallel with the colorimetric phenylarseneoxide titration. Excellent agreement was found in the chlorine residuals obtained by the two methods.

Other indicators used in the investigation, besides those previously mentioned, were neutral ortho-tolidine reagent and neutral benzidine reagent. Both of these reagents give a color reaction of similar type and sensitivity. With chloramines the neutral ortho-tolidine reagent produces directly a blue-green color, which is readily dis-

tinguishable in sewage, but which disappears very rapidly.

Procedure

To minimize the variation which might result from the dosing of parallel samples of sewage with chlorine water, a spot plate technique was established which would permit the use of the same sample for all the indicators. A large spot plate was used and the indicators were placed in the cavities as follows:

1. Two drops of the p-aminodimethylaniline reagent plus one or more small crystals of potassium iodide.
2. Two drops of neutral ortho-tolidine reagent.
3. Two or three drops of acid ortho-tolidine reagent.
4. One drop of 10 per cent phosphoric acid plus two or three drops of standard starch-iodide reagent.
5. Two or three drops of starch-iodide reagent.

An immediate chlorine demand (ICD) is run on a sample of raw sewage or primary treatment effluent, and from the demand thus determined a series of six 200-ml. samples are dosed with standard chlorine water in incre-

TABLE I.—Comparison of Chlorine Demand Determinations[1] on Influent Sewage by Various Indicators[2]

Sample No.	PAD +KI	Neutral O-T	Acid O-T	Mod. Acid S-I	Neutral S-I
1	6.2	7.1	> 7.6	6.2	7.6
2	4.1	4.6	> 4.6	4.1	4.6
3	4.4	4.8	6.5	4.6	4.8
4	5.1	5.1	7.3	5.1	6.2
5	6.2	6.2	9.0	6.2	8.4
6	6.7	6.7	> 9.9	6.7	8.9
7	5.4	5.9	> 8.6	5.9	8.1
8	5.4	7.0	> 8.6	5.4	7.0
9	5.4	6.5	8.1	5.4	6.7
10	6.7	6.7	9.4	6.7	7.8
11	7.4	8.0	>10.3	7.4	9.1
12	16.2	16.8	>22.2	17.1	22.2
13	11.3	11.3	16.5	11.3	12.4
14	6.8	6.8	8.7	6.8	8.3
15	3.9	4.5	—	3.9	4.5
16	5.7	6.0	—	6.0	6.8
17	5.7	5.2	—	5.7	6.2
18	7.3	9.2	—	7.3	9.7
19	4.0	4.5	—	4.0	5.6
20	9.4	9.4	—	9.2	10.2

[1] Expressed in p.p.m. Cl_2.
[2] PAD = para-aminodimethylaniline; O-T = ortho-tolidine; S-I = starch-iodide.

TABLE II.—Comparison of Chlorine Demand Determinations[1] on Primary Effluent by Various Indicators[2]

Sample No.	PAD+KI		Neutral O-T		Mod. Acid S-I		Neutral S-I	
	10 min.	15 min.	10 min.	15 min.	10 min.	15 min.	10 min.	15 min.
1	4.7	4.9	5.2	5.4	4.7	4.9	5.9	6.2
2	6.2	6.7	6.7	7.2	6.2	6.7	7.7	7.9
3	5.7	6.2	6.4	6.9	5.4	6.4	7.7	7.9
4	—	3.5	—	3.5	—	3.5	—	4.7
5	3.2	3.7	4.0	4.2	3.2	3.2	4.2	4.7
6	—	3.2	—	3.0	—	3.0	—	4.3
7	4.3	4.6	4.9	5.4	4.3	4.6	5.7	5.9
8	4.9	5.1	5.4	5.7	4.3	4.3	6.2	6.5
9	—	4.7	—	—	—	4.7	—	>5.1
10	—	4.8	—	—	—	4.8	—	6.1
11	—	3.9	—	—	—	3.9	—	4.9
12	—	4.3	—	—	—	4.3	—	5.0
13	—	3.0	—	—	—	3.0	—	>3.5
14	—	3.4	—	—	—	3.4	—	4.2
15	—	5.3	—	—	—	5.3	—	6.6
16	—	4.0	—	—	—	4.0	—	5.6

[1] Expressed in p.p.m. Cl_2.
[2] PAD = para-aminodimethylaniline; O-T = ortho-tolidine; S-I = starch-iodide.

ments of 0.1 or 0.2 ml. At the end of 10 and/or 15 min., 1-ml. samples for each indicator are withdrawn from each flask and placed in the spot plate depressions containing the indicators. The exact demand may be estimated by the intensity of color in the cavity representing the smallest excess of chlorine.

In the case of para-aminodimethylaniline, the color sought is an immediate pink. Interference by air oxidation and other substances is rapid. Neutral ortho-tolidine produces an immediate blue-green color which is flashy and disappears rapidly. The acid ortho-tolidine produces a yellow to orange in less than 60 sec.; however, samples were permitted to stand up to 5 min. without subsequent color development. The modified acid starch-iodide produces an immediate blue color, which is stable but may be slightly intensified by air oxidation of iodide on standing. The neutral starch-iodide produces an immediate blue color, which fades rapidly in sewage.

The procedure for running the comparative chlorine residual tests by the modified acid starch-iodide and colorimetric phenylarseneoxide methods was set up to reduce to a minimum the variables resulting from dosing separate samples of sewage. Sewage samples (400-ml.) were dosed with varying amounts of chlorine to the limits established by the chlorine demand test. At the end of the contact period each sample was divided into two 200-ml. portions. To one portion was added the premixed reagent (2 ml. of 10 per cent phosphoric acid plus 5 ml. of starch-iodide reagent) and the resulting blue color was titrated with 0.00564 N sodium thiosulfate. To the other portion were added, in the following order with agitation, 5 ml. phenylarseneoxide reagent, a small amount of potassium iodide crystals, 2 ml. N hydrochloric acid, and starch reagent. The excess phenylarseneoxide was then back titrated with 0.0282 N iodine solution from a microburette.

Reagents

Para-aminodimethylaniline reagent. Both the saturated solution of the reagent in acetone and the 0.02 per cent solution in alcohol were used.

Potassium iodide crystals, c.p.

Neutral ortho-tolidine reagent. Dissolve 1.35 g. ortho-tolidine hydrochloride in 1 l. of distilled water.

Acid ortho-tolidine reagent. Standard solution of ortho-tolidine hydrochloride in dilute HCl.

Starch-iodide reagent.

10 per cent ortho-phosphoric acid solution.

TABLE III.—Comparison of Chlorine Residuals[1] Obtained by Modified Acid Starch-Iodide and Phenylarseneoxide Methods

Sample No.	Contact Time (min.)	Chlorine Residual (p.p.m.)		
		PAO[2]	Mod. Acid S-I	Difference
1	10	0.77	0.94	−0.17
1	10	0.28	0.49	−0.21
1	10	1.36	1.33	+0.03
2	10	0.64	0.68	−0.04
2	10	0.59	0.69	−0.10
2	10	0.75	0.89	−0.14
2	10	0.64	0.56	+0.08
2	10	0.80	0.80	—
2	10	0.85	1.15	−0.30
2	10	0.80	0.80	—
3	10	0.39	0.30	+0.09
3	10	0.28	0.30	−0.02
3	10	0.28	0.22	+0.06
4	15	0.28	0.30	−0.02
4	15	0.90	0.50	+0.40
5	15	1.82	1.92[3]	−0.10
6	15	1.05	0.90[3]	+0.15
6	15	1.26	1.36[3]	−0.10
6	15	1.75	1.95	−0.20

[1] With chlorine added in excess of demand.
[2] Phenylarseneoxide.
[3] In these samples the H_3PO_4 + KI solutions were added to the chlorinated sample; the iodine released was then discharged with phenylarseneoxide, the excess of which was titrated with standard I_2 solution.

Phenylarseneoxide solution. Wallace and Tiernan, 5 ml. of solution equivalent to 1 p.p.m. Cl_2 in a 200-ml. sample.

Hydrochloric acid, 1 N.

Thiosulfate standard solution, 0.00564 N.

Iodine standard solution, 0.00564 N.

Iodine standard solution, 0.0282 N.

Discussion

Tables I and II give typical results from the series of spot plate tests performed as noted above on raw sewage and primary effluent, respectively. The tests were somewhat more difficult to perform on the influent and the results are variable, showing the interferences from the high turbidity and interfering substances in the sewage. However, agreement between the para-aminodimethylaniline and the modified acid starch-iodide tests was generally excellent.

The neutral ortho-tolidine test gave many checks with the p-aminodimethylaniline and modified acid starch-iodide determinations, but was more difficult to read, due to the rapid disappearance of the color. The acid ortho-tolidine and neutral starch-iodide tests showed no correlation between themselves and the other tests, except that they were consistently higher. In primary effluent the agreement between p-aminodimethylaniline and modified acid starch-iodide was very good. Preliminary tests indicated that acid ortho-tolidine would perform in the same manner in the effluent as in the influent, so the indicator was eliminated from further consideration.

The acid starch-iodide titration for chlorine residual was compared with the colorimetric phenylarseneoxide (3), with results as shown in Table III. Agreement, in general, is good between the two methods. However, it is quite difficult to titrate out the blue starch-iodine complex from the turbid influent and many partially clarified samples. The end-point is difficult to see and the blue color may be adsorbed by the suspended and colloidal solids present and released slowly, thus preventing a sharp end-point.

PART II. MODIFIED AMPEROMETRIC AND TITRATION PROCEDURE FOR CHLORINE RESIDUALS IN SEWAGE

As a result of the difficulties encountered in titrating out the blue starch-iodine color in Part I above, several experiments were undertaken which indicated interesting modifications in the phenylarseneoxide procedure. Sodium thiosulfate was substituted for phenylarseneoxide with excellent results. The standard solution is easy to prepare, generally available, simple to standardize, and relatively stable. It is essential to include the potassium iodide, which releases the iodine to react in turn with the thiosulfate, in the thiosulfate reagent. The potassium iodide does not affect the stability of the solution if it is protected from sunlight.

Both the 0.0282 N and 0.00564 N iodine solutions were used for titrating the thiosulfate-iodide and the phenylarseneoxide reagents. An appreciable error may be introduced in titrating with the 0.0282 N iodine, and inconsistencies in the stability of the 0.0282 N and 0.00564 N iodine solutions were found. Solutions of potassium iodate and bi-iodate, 0.00564 N in strength, were used with excellent results in the titration of both sodium thiosulfate and phenylarseneoxide in acid solution. Iodine is released by the iodates in acid solution with sufficient rapidity to give a good end-point. The iodates are extremely stable and may be obtained in purity adequate for their use as primary standards.

An amperometer satisfactory for the determination of chlorine residuals in

sewage was devised by using a Leeds and Northrup portable potentiometer. The galvanometer on this instrument has a sensitivity of 0.5 microamperes per scale division. A cell was constructed from a fritted glass crucible of fine porosity by inserting a silver rod or wire into saturated potassium chloride within the crucible and winding the platinum electrode as a spiral on the outside of the fritted glass. The sewage or water under test was agitated with a magnetic stirrer. The cell was immersed in the solution to be tested and connected to the potentiometer through the terminals provided for a cell of unknown e.m.f. The potentiometer was then balanced to place the galvanometer in the vicinity of the center of the scale. A minute excess of free iodine causes a sharp deflection of the galvanometer.

Almost any pH meter commonly found in many laboratories, such as the Beckman model G or the Macbeth line-operated continuous-indicating pH meter, may be used similarly.

TABLE IV.—Comparison of Colorimetric and Amperometric End Points

Sample No.	Description	Chlorine Residual (p.p.m.)		
		Amperometric	Titration	Difference
1	Tap water	0.50	0.33	0.17
2	Tap water and Cl_2	1.55	1.35	0.20
3	Sewage and Cl_2	3.85	3.65	0.20
4	Sewage and Cl_2	3.23	3.05	0.18
5	Sewage and Cl_2	3.68	3.45	0.23
Average	—	—	—	0.20

The determinations were also performed using the starch end-point, with similar results. The amount of iodine or iodate necessary to produce a visible color is slightly greater than that required to give an end-point with the amperometric method, but the difference is fairly constant, as shown in Table IV. The greatest difficulty with the colorimetric method lies in the inability to detect the end-point in highly-colored or turbid solutions.

Reagents

0.00564 N $Na_2S_2O_3$ containing 20 g. KI, 10 mg. HgI_2, and 4 g. $Na_2B_4O_7$ per liter.

0.00564 N KIO_3. Prepared from N/40 KIO_3 by dilution.

0.0282 N I_2 solution containing 25 g. KI per liter.

0.00564 N I_2 solution. Prepared from the above by dilution and the addition of 10 g. KI per liter.

Phosphoric acid solution, 10 per cent.

Starch-iodide solution.

Procedure

To a 200-ml. sample of which the chlorine residual is to be determined, add exactly 5 ml. of 0.00564 N thiosulfate solution rapidly with agitation. As 1 ml. of the standard thiosulfate solution is equivalent to 1 p.p.m. chlorine in a 200-ml. sample, this will cover residuals up to 5 p.p.m. For residuals in excess of 5 p.p.m. a larger amount of the reagent should be used. Add 2 ml. of 10 per cent phosphoric acid solution, 5 ml. of starch-iodide solution, and immediately titrate with 0.00564 N potassium iodate solution to the blue starch complex or to a permanent deflection with the amperometer. As 1 ml. of the iodate reagent is equivalent to 1 ml. of the thiosulfate reagent, the chlorine residual, in p.p.m. of chlorine, is equal to the milliliters of thiosulfate minus the milliliters of iodate. The procedure is the same when using the standard iodine solution.

Discussion

Sodium thiosulfate, in general, is considered unstable in acid solutions. There are several instances that have been found, since the above method was developed, where similar titrations have been carried out with success. Furman and Wallace (7) have used an identical method to determine thiosulfate by titrating with ceric sulfate standards; preliminary work in the Detroit sewage treatment plant laboratory indicates that standard ceric sulfate

TABLE V.—Stability of Standard Sodium Thiosulfate Solutions in the Presence of Phosphoric Acid, pH 2.5

Sample	$Na_2S_2O_3$ (ml.)[1]	Time (min.)	Iodine Sol. Used (ml.)[2]
Distilled water	3.00	1	3.00
Distilled water	3.00	5	3.00
Distilled water	3.00	10	3.00
Distilled water	3.00	15	3.00
Distilled water	5.00	30	4.98
Distilled water	5.00	1	5.01[3]
Distilled water	5.00	10	5.00[3]
Distilled water	5.00	30	5.02[3]
Sewage 1	5.00	1	5.15[3]
Sewage 1	5.00	10	4.95[3]
Sewage 1	5.00	30	4.70[3]
Sewage 2	5.00	1	5.10[3]
Sewage 2	5.00	10	4.97[3]
Sewage 2	5.00	30	4.70[3]

[1] Milliliters of 0.00564 N sodium thiosulfate in 200-ml. sample.

[2] 0.00564 N iodine solution.

[3] Samples titrated with 0.00564 N potassium iodate solution.

solutions may be used instead of the iodate.

Table V gives part of a number of similar determinations to demonstrate the stability of sodium thiosulfate under the conditions of the method. In distilled water the stability of the thiosulfate is excellent, with no variation in 30 min. However, in sewage the breakdown of the thiosulfate in acid solution appears to be slowly catalyzed by some substance. The breakdown was noted whether or not iodide was added to the sewage with the thiosulfate. As long as the titration is made within 10 min. after the addition of the reagents, the error is not more than 0.1 p.p.m. Phenylarseneoxide was found to be equally unstable in acid sewage mixtures. Where the thiosulfate was added to neutral sewage and the acid was not added until immediately before the titration, no breakdown of the thiosulfate was found in a 30-min. period. Therefore, if the solution is not acidified until immediately preceding titration, this error, slight as it is, can be entirely avoided.

In Table V it will also be noted that a slight excess of oxidant is required to complete the titration in the first portions of each sewage sample. This results in what might be called a negative residual, and is apparently due to the absorption or reaction of iodine in the acid sewage by substances present. It is believed that these substances are readily oxidized by chlorine and in chlorine residual determinations the error will be negligible.

As noted above, iodine is released almost immediately when potassium iodate is introduced into an acid iodide solution. The end-point is not perceptibly delayed and may be considered to be immediate. The potassium iodate solution is stable for an indefinite period, no change having been found in several weeks.

The sodium thiosulfate solution containing sodium tetraborate (borax) and mercuric iodide as a preservative is superior to that recommended by "Standard Methods" (1).

Table VI is a comparison of the chlorine residuals found amperometrically on the same sample using phenylarseneoxide. The determination was performed by dosing a large sample with excess chlorine and removing two 200-ml. portions for the determination. No significant differences are shown where

TABLE VI.—Comparison of Amperometric Titration of Residual Chlorine by Phenylarseneoxide and Acid Thiosulfate-Iodide Methods

Sample	Chlorine Residual (p.p.m.)	
	PAO[1]	Acid $Na_2S_2O_3$-KI
Tap water	0.35	0.37
Tap water	1.77	1.74
Primary sewage	0.97	0.95
Primary sewage	4.65	4.54
Primary sewage	3.77	3.75
Primary sewage	4.68	4.69
Primary sewage	4.47	4.40
Primary sewage	4.48	4.48

[1] Phenylarseneoxide method.

the titration is carried out immediately following the addition of the reagents.

The data in Table VI were obtained using standard iodine solution prior to the development of the iodate standard solution. As part of the research into the application of the method herein described, many determinations were run in which a comparison of the iodate and iodine standard solutions were made against both phenylarseneoxide and thiosulfate. There is no difference between the results obtained with either material.

The acid starch-iodide procedure outlined in Part I was used as a qualitative test to indicate a titratable residual in a sample before adding the sodium thiosulfate solution to another portion.

The difference between the amperometric and colorimetric determinations as shown in Table IV varied from 0.17 p.p.m. to 0.23 p.p.m., with an average of 0.20 p.p.m. higher Cl_2 residuals for the amperometric method. This agrees well with data by Marks, Joiner, and Strandskov (3) showing a variation of 0.15 to 0.30 p.p.m. and an average of 0.21. Using the 0.00564 N oxidizing agent instead of the 0.0282 N reagent reduced the average difference to about 0.15 p.p.m. By applying this value to either method, the one determination can be compared with the other with a fair degree of accuracy.

Although additional work on the application of the new methods of determining chlorine residuals and demands is continuing and will be reported in a future paper, it is believed important at this time to present some of the preliminary conclusions so far drawn. The data thus far obtained agree well with those obtained in experiments by Wallace and Tiernan Co. (3) (5), which showed that chlorine residuals greater than 2.0 p.p.m. could be obtained by the phenylarseneoxide method before any residuals were obtained with the acid ortho-tolidine method. The phenylarseneoxide method and the acid thiosulfate-iodate method do measure compounds which exert considerable action against bacteria and which are not measured by the ortho-tolidine reagent. The statement by Heukelekian and Day (8), that this is not substantiated by the results of their experiment, is not supported by the data presented on page 161, and particularly in Table IV, of their paper.

The chlorine residuals found by the phenylarseneoxide and the acid thiosulfate-iodide methods account for the excellent bacterial kill results for subortho-tolidine residuals reported by Rudolfs and Ziemba (9), Symons and Simpson (10), Beardsley (11), and others. In the work reported herein it has been found, in contact periods up to 30 min., that where no residual is found by the new titration methods there is no reduction in the coliform indices, and that there is a definite relationship between the chlorine residual as determined above and the reduction in M.P.N. This leads to the premise that so-called subresidual chlorination is a misnomer, as there are actually present in the sewage compounds resulting from the chlorination of the sewage which have a bactericidal action and are readily determined.

Summary and Conclusions

A modification of the starch-iodide method for determining chlorine residuals and several variations of the phenylarseneoxide determination for chlorine residuals have been presented herein. These methods provide new tools for a thorough study of and the control of sewage chlorination. Sodium thiosulfate has been found to be sufficiently stable in dilute phosphoric acid solutions as an analytical reagent, and may be readily titrated with standard iodine, potassium iodate, or ceric sulfate solutions, in the presence of potassium iodide, to a starch-iodine end-point. The sodium thiosulfate solution containing potassium iodide may

be used to discharge chloramine residuals in sewage or water, and the chlorine residual may be determined by a back titration of the unreacted sodium thiosulfate in an acid solution.

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COMPARATIVE STUDY OF VACUUM FILTER CLOTHS *

By Arnold B. Joseph

Johns Hopkins University, Baltimore, Md.

Much has been written of the vacuum filtration process, but little has been said of the choice of filter cloths. In general, a woolen or cotton cloth is recommended, with conflicting reasons for the choice. The literature reports that many operators have tried various cloths, such as glass, "plastics," burlap, and woven metal cloths, and all have been unfavorable.

The method of testing does not give a true indication of the cloths' ability. That is, a patch of the testing material is sewn in with the regular cloth and subjected to the same conditions as the cloth in use. A better test would be to cover the entire filter with the testing cloth and vary the filter speed, chemical dose, and submergence. The best results of this test could then be compared with those of the regular cloth.

Test Procedures

Buchner Funnel Test

The Buchner funnel was tried, but the results from these tests were too similar for all cloths to draw any conclusions.

Filter Leaf Test

A filter leaf apparatus was the nucleus for the tests reported herein. The filter leaf itself is a short, hollow, brass cylinder (90 mm. in diameter by 16 mm. deep) with one end open. The open end is first covered with a coarse screen and the material to be tested is clamped atop the screen. The inside bottom of the filter leaf is sloped to an outlet. A short section of copper tubing soldered to the outlet hole enables one to connect the filter leaf with a filtrate collection tube and the necessary vacuum or suction. In testing position, the filter leaf nestled on the bottom of a large glass jar (a 5-qt. oil can would have done as well) and the chemically conditioned (ferric chloride) sludge was poured in over the leaf. While the sludge was being poured onto the filter, it was protected by an inverted Imhoff cone so no sludge would be forced into the cloth. After pouring, the cone was withdrawn, the vacuum adjusted by the bleed to the desired amount, then the vacuum valve was opened and a stopwatch simultaneously started. At one minute of submergence, a plug was removed from the bottom of the jar, running the excess sludge to waste. When the vacuum had dropped 10 mm. of mercury, it was stopped. Compressed air was then applied to the filter leaf to loosen the dried sludge cake and the discharging properties of the cloth were noted.

Dipping Test

The cloths were dipped into two solutions—one of ferric chloride and one of ferric chloride plus lime. The pH governed the strength of the solutions. A 10 per cent solution of ferric chloride was added to tap water of pH 6.7 until pH 3.5 was reached. The lime plus ferric chloride solution was made by adding 15 ml. of 10 per cent ferric chloride to one liter of water, then adding lime in slurry form until pH 10.5 was reached.

Structurally speaking, the cloths were not changed in 312 hr. of dipping. However, they did adsorb the

* Condensation of thesis submitted by the author to Johns Hopkins University.

floc formed in the mixing of the ferric chloride and lime. This pH changed from 10.5 to 9.0. The cotton cloths showed the least weight change from dipping in either solution and the silk and the wool gained the most. All the cloths, except wool, picked up the lime floc as a superficial coating, but the wools were impregnated.

Analysis of Results

Vinyon

The vinyon cloth had a hard, smooth finish and tended to unravel rather easily. The smooth finish and relatively open pores accounted for the high turbidity produced (over 1,000 p.p.m.) in the filtrate. After testing, it gained slightly in weight from sludge uptake by the cloth. The sludge cake produced and its relative moisture did not change much over three cycles. As the sludge cake was being formed, it compressed into the pores of the cloth. This made it necessary to lift the cake out of the cloth, because the air pressure was not sufficient to blow the sludge loose. If used with a scraper, compression into the pores may cause blinding of the cloth. Particulate matter was noticed interspersed within the threads of the cloth after the first cycle, which may tend to make cleaning a tedious job after continuous operation. The time necessary to reach the vacuum break in the third cycle of operation was 13 min.

Wool with Nap

Wool cloth with nap gave very consistent results as far as time of drying, cake production, and uniformity of drying (moisture percentage) were concerned. There was a very noticeable drop in the amount of filtrate collected with successive cycles. The turbidity started and remained at a low stage. The cake did not freely leave the cloth after the air blow; in fact, it tended to stick to the nap. After several runs, the nap had accumulated a coating of sludge, which acted to alleviate the sticking. Nevertheless, the cake still adhered to the nap. This tendency might also lead to blinding when the cloth is used in conjunction with a scraper. This was the thickest cloth used and it also gathered and held the greatest amount of sludge, mostly in the nap. The nap kept the sludge from getting into the cloth weave. The time to reach the vacum break in the third cycle was 8.5 min.

Wool—Plain Weave

Wool cloth with plain weave gave very consistent results in time of drying, cake production, and uniformity of drying. Here, too, there was a noticeable drop in the amount of filtrate collected with successive runs. This cloth also gained weight from sludge picked up in the weave. The turbidities of the filtrates were rather low. The cake was discharged freely and easily when air blow was applied. The time to reach the vacuum break in the third cycle was 8.5 min.

Silk

The silk material was very tough to penetrate with the screws when being applied to the filter leaf and did not tend to unravel as did the vinyon and glass. The silk cloth gave very consistent results in cake production and degree of dryness. It also gave a relatively high turbidity. The total filtrate decreased with successive runs, although the cloth did not pick up sludge in the weave after the first dose. The cake discharged very easily with the air blow, no pull being needed to remove it. Here again, the cake compressed into the pores as in the vinyon test, but because of the smaller size of the pores this had very little effect on the ease and cleanness of cake discharge. The time to the vacuum break in the third cycle was 8 min.

Glass

The glass cloth was the most difficult to manage. The glass fibers are

relatively stiff, which makes this cloth very easy to unravel. If the cloth has to be cut it almost falls apart at the edges. Using this cloth, smaller cake yields were obtained as the cloth was re-cycled. When air blow was applied, it completely discharged the cake from the cloth. Not much weight gain occurred with use; that is, very little sludge adhered to the cloth. After each cycle it took slightly longer for the cake to dry. The glass cloth had very little elasticity; when air blow was used the cloth bulged out and stayed out until sludge and vacuum were again applied. The time to the vacuum break in the third cycle was 11 min.

Nylon

Nylon cloth gave very consistent results in time of drying, cake production, and degree of dryness. The cake on this cloth took the longest time to dry. Using this cloth, the filtrate had very little turbidity. The cake was slightly compressed into the pores, but still disharged easily and left very little sludge in the weave of the cloth. It took 13 min. to reach the vacuum break in the third cycle.

Cotton Twill

Cotton twill as a filtering medium took increasingly longer times to attain the end point of cake dryness. It gave successively smaller yields, but held the turbidities and moisture percentages in the cakes relatively constant. It continually picked up more sludge in the weave as it was re-cycled. The cake did not discharge cleanly, leaving chunks of sludge behind in the weave, but it did leave the cloth easily when the air blow was applied. After the third cycle, the fibers were thoroughly interspersed with small lumps of vacuum-dried sludge. It took 10 min. to reach the vacuum break in the third cycle.

Cotton With Nap

Cotton cloth with nap showed little variance in rate of filtering with successive cycles, although it did show a steady decline in cake production. The cake tended to stick to the nap when air blow was applied. This sticking may initiate some streaks of blinding when used with a scraper. After each run, the sludge cakes on this cloth took progressively longer to dry. Time to vacuum break in the third cycle was 8 min.

The amount of sludge held in the cloths seems to be a function of the cross-section of the fibers. Silk, which gained very little total weight due to adhering sludge, has the highest weight gained per unit thickness

TABLE I.—Comparison of Vacuum Filter Cloth Performances

Cloth	Filtered at 5 Min.[1] (%)	Filtrate Turbidity (p.p.m.)	Moisture in Cake (%)	Sludge Uptake (g.)[2]	Sludge Uptake per Unit Thickness (mg./0.001 in.)
Napped cotton twill	94.7	25	74.7	0.090	2.14
Vinyon	96.4	1,000+	78.0	0.095	2.50
Napped wool	94.4	75	74.6	0.480	3.45
Wool flannel	92.9	25	76.6	0.230	3.54
Glass	90.1	25	75.2	0.005	0.50
Nylon	87.1	10	75.9	0.095	2.97
Silk	93.5	215	76.6	0.063	7.00
Cotton twill	92.2	25	76.8	0.105	1.80

[1] The maximum time of revolution of a drum-type vacuum filter is approximately 5 min. This column gives the percentage of the final dryness which the cake attained in 5 min. of the third cycle of operation.

[2] Weight of dry sludge retained on or in the cloth after the third cycle; gives some indication of the relative number of cleanings needed.

TABLE II.—Summary of Vacuum Filter Cloth Performances

Order No.	Cake Production	% Filtered at 5 Min.	Filtrate Turbidity	Moisture in Cake	Sludge Uptake per Unit Thickness	Cake Discharge[1]	Cost of Fiber per Lb. (1946)
1	Vinyon	Vinyon	Nylon	N. cotton	Glass	Glass	Cotton
2	Silk	N. cotton		N. wool	Cotton	Fl. wool	Wool
3	Fl. wool	N. wool	N. cotton Glass Fl. wool Cotton	Glass	N. cotton	Silk	Vinyon
4	Cotton	Silk		Nylon	Vinyon	Nylon	Glass
5	N. wool	Fl. wool		Fl. wool Silk	Nylon	Vinyon	Nylon
6	N. cotton	Cotton	N. wool		N. wool	Cotton	Silk
7	Glass	Glass	Silk	Cotton	Fl. wool	N. wool	
8	Nylon	Nylon	Vinyon	Vinyon	Silk	N. cotton	
			Column Weight				
	5	1	1	3	1	2	10

[1] Listed in order of ease and cleanness of discharge from best to worst.

(Table I). The silk fiber has a triangular cross-section and the fibers are woven in pairs. This would account for the uptake of very fine particles. The silk cloth also had the highest thread counts. However, this cloth did not gain any weight after the first run or cycle. Glass cloth, which has a smooth hard finish and a circular fiber, held very little sludge. The nylon had a finish similar to a worsted type wool. The uptake of the nylon cloth, which seems rather high for a circular, smooth, uniform fiber, is attributed to the rough finish of the cloth. The woolen cloths, having fibers that are scaly and crimped, caught and held the largest amounts of sludge of all the cloths. The vinyon cloth has dumbbell-shaped fibers, loosely woven, which explains the relatively high uptake for it.

Summary

Table II lists the cloths in descending order of performance obtained in cycle three of the filter leaf test, which is probably the most significant of all the tests. An attempt has also been made to score each cloth according to

TABLE III.—Rating of Vacuum Filter Cloths[1]

	Glass	Vinyon	Silk	Nylon	Wool Flannel	Napped Wool	Cotton Twill	Napped Cotton Twill
Cake production	35	5	10	40	15	25	20	30
5-min. filtration	7	1	4	8	5	3	6	2
Filtrate turb.	2	8	7	1	2	6	2	2
Cake moisture	9	24	15	12	15	6	21	3
Sludge uptake	1	4	8	5	7	6	2	3
Cake discharge	2	10	6	8	4	14	12	16
Cost	40	30	60	50	20	20	10	10
Total	96	82	120	124	68	80	73	66
Less cost	56	52	60	74	48	60	63	56

[1] Factors weighted in accordance with Table II.

its performance in the other tests, as shown in Table II.

Table II also lists the cloths in order of relative cost of the fibers per pound. Because cost is the most important factor in cloth selection, this column has been given the highest weighting—that is, 10. Other weight factors are shown beneath each column. The lower the total score for each cloth, the better the individual cloth rating.

To illustrate a cloth's rating, silk will be tabulated for its performances. In cake production, silk ranked second. As the cake production is weighted 5, the score for silk is $5 \times 2 = 10$. The next column is weighted 1 and the silk cloth is fourth in relative performance. Its score now becomes $10 + 4 \times 1 = 14$. By following the same procedure for the other columns the total score for silk equals 120. Each of the other cloths is rated in the same manner.

Table III, a compilation of the column ratings from Table II, shows the relative scores for the eight different cloths. The results of Table III show that cotton with nap is rated best, with plain wool second, cotton twill third, etc. If all the fibers were the same price, there would be less difference in their scores, and the ratings would then fall back on the relative performances of the cloths. With costs eliminated, the plain wool cloth has the lowest rating.

It is hoped that this thesis will prompt further research on filter cloths for sewage sludge filters. A study should be made of cloth durabilities under extended use, for durability is one of the most important properties governing the final selection of a filter cloth.

REFUSE COLLECTION COSTS NOT GROUND AWAY

All the refuse disposal problems of cities cannot be ground away. This is the conclusion of public works officials after a study of the effect of installation of household garbage grinders on municipal refuse collection and disposal.

A section of the American Public Works Association's special report, "An Evaluation of Household Food Waste Disposers," points out that garbage composes less than 10 per cent of the total volume of refuse. Therefore, even if the grinders were adopted universally, it would still be necessary to collect and dispose of the remaining 90 per cent of refuse.

Inasmuch as the larger proportion of municipal refuse cost is in collection, cities will save little by having 10 per cent of the material to be collected removed, the report observes. It will still be necessary to expend nearly as much labor and truck time to make collections from each house, although the frequency may be a little less. Then, too, if a city incinerates that part of its refuse which is combustible, a problem of holding down the temperatures arises if all garbage has been removed.

At best, it might be possible for a city to save 20 per cent of its refuse collection costs if each home had a garbage grinder, it is estimated. However, this saving may be more than offset by the cost of new facilities necessary to handle the increased sewage requiring treatment. If a city has no sewage treatment plant, or if the existing plant has excess capacity, there would be no immediate need for larger facilities, of course.

ACTIVATED SLUDGE STUDIES

III. EFFECT OF pH OF SEWAGE ON THE ACTIVATED SLUDGE PROCESS *

By C. E. Keefer and Joseph Meisel

Deputy-Sewerage Engineer and Senior Chemist, respectively, Bureau of Sewers, Baltimore, Md.

The effect of the pH of sewage on the activated sludge process has been studied by several investigators. As the results of these investigations and their interpretation have not been entirely consistent, a series of laboratory experiments were conducted to throw additional light on this problem.

Previous Studies

In 1930, Baly (1) discussed the mechanism of the activated sludge process and indicated the part played by the pH of sewage in the process. He stated that the isoelectric point of sewage colloids is at about pH 4.6 and that this value increases with an increase in the electrolytes in the sewage. In normal sewage the isoelectric point is about pH 6.5. The colloids are electronegative if the pH of the sewage is greater than 6.5 and electropositive if the pH is less than 6.5. Baly suggested that by adjusting the pH of sewage to about 5.8 to 6.0 the sewage colloids would be rendered electropositive and would flocculate the sewage bacteria, which carry an electronegative charge. He failed to include in his discussion any reference to the effect of the pH of the sewage on the removal of materials in solution by the activated sludge process.

Beedham (2) conducted a series of laboratory experiments at Bradford, England, over the somewhat limited pH range from about 4.0 to 7.5 to determine the pH at which the process was most effective. He concluded that the best results were obtained when the pH was just below 7.0. No studies were made with a pH greater than 7.5. A more extensive group of laboratory experiments were conducted by Lumb (3) at Halifax, England, at pH values between 2.0 and 8.5 with aeration periods varying from 1 to 8 hr. Colloid removal was best at a pH of approximately 6.5.

Ruchhoft, Kachmar, and Moore (4) studied the removal of glucose by the activated sludge process at pH values from 3.9 to more than 11.5 and with periods of aeration varying from 30 min. to 22.5 hr. At a pH below about 6.0 the rate of glucose removal was reduced and at a pH of 3.9 action practically stopped. There was little reduction in glucose removal at a pH as high as 9.6. In a study of the growth requirements of *Sphaerotilus natans* Ruchhoft and Kachmar (5) observed that pH values below 5.0 and between 8.5 and 10.0 were detrimental to *Sphaerotilus* growth. At the sewage plant serving Kyoto City, Japan, Chujo (6) reported that the activated sludge effluent was improved by reducing the pH of the sewage from 9.0 and higher to about 7.0.

A comprehensive study of the use of lime and its attendant effect on the pH of sewage to control the bulking of activated sludge was made by Haseltine (7). The zooglea-forming bacteria isolated in pure culture from activated sludge by Butterfield (8) was observed to grow over a pH range from 5.6 to

* Parts I and II of this series appeared in This Journal, **22**, 9, 1117 (Sept., 1950); and **22**, 12, 1518 (Dec., 1950).

8.5. Optimum growth appeared to be at a pH of about 7.0 to 7.4.

Woolridge and Standfast (9) studied the oxygen absorption of sewage-activated sludge mixtures at pH values ranging from 4.0 to 10.0 by means of Barcroft differential manometers. They observed most rapid oxidation between pH 6.0 to 9.0 with a possible optimum at about 7.3. Oxidation was less rapid at pH 5.0 and 10.0, with complete inhibition at pH 4.0. Of necessity, they worked with very small amounts of materials. Two ml. of sewage was mixed with 0.5 ml. of activated sludge and 0.5 ml. of the requisite buffer. The extent to which impurities were removed from the sewage was not given.

Levine and Soppeland (10) studied the effect of various bacteria isolated from activated sludge on the decomposition of gelatin and milk proteins under aerobic conditions. They observed that the optimum reaction for proteolysis was at a pH from 7.0 to 7.5. No appreciable inhibition resulted under aerobic conditions at a pH as low as 6.4. However, at a pH of 5.0 to 5.5 proteolysis frequently stopped. There was a tendency for the more acid inoculations to become alkaline and the more alkaline to become acid.

Experimental Procedure

Three series of experiments were conducted to determine the effect of the pH of sewage on the efficiency of the activated sludge process. The results of the first two series are not reported, as the work was of a preliminary nature. Settled sewage was obtained from the primary settling tanks at the Back River sewage treatment works. Approximately 10 l. of this material was placed in each of eight 5-gal. glass battery jars. To each jar sufficient fresh activated sludge, as discharged from the final settling tanks at the Back River plant, was added to give a mixed liquor containing approximately 1,000 p.p.m. of suspended solids. Hydrochloric acid or sodium hydroxide was added to 7 of the jars to adjust the pH of the materials to approximately 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, and 10.0. No chemical was added to the eighth jar, which served as a control.

The third series of experiments covered a period of 12 days. The contents of each jar was aerated for 4 hr. and then allowed to settle quiescently for 2 hr., after which time the supernatant was siphoned off, fresh primary settling tank effluent was added and the process was repeated. During this 12-day period 10 groups of analyses of the untreated and the treated sewage were made.

Results Obtained

Table I gives the analyses of the sewage before aeration. Preliminary B.O.D. tests of the treated sewage, the pH of which had been adjusted above and below normal, gave erratic results. This test, therefore, was not made. In its place oxygen consumed was determined. The more important physical and chemical analyses after the 4-hr. aeration period and the 2-hr. settling period are given in Table II. For the sake of brevity, only 5 of the 10 groups of analyses are given. The reduction in oxygen consumed is shown graphically in Figures 1 and 2. The temperature of the sewage during the 12-day test period varied from 16° to 20° C. The dissolved oxygen in the mixed liquor was never less than 7.2 p.p.m.

TABLE I.—Analysis of Settled Sewage Before Aeration

Test No.	Oxygen Consumed (p.p.m.)	Susp. Sol. (p.p.m.)
1	129	376
2	108	167
3	108	140
4	85	90
5	94	149
6	62	105
7	125	178
8	120	188
9	110	112
10	110	96

TABLE II.—Analysis of Settled Sewage After Aeration and Final Settling

pH at Start	After 4-hr. Aeration		Effluent After 2-hr. Settling				
	pH	Sludge Index	Oxygen Consumed		Susp. Solids		pH
			(p.p.m.)	Red. (%)	(p.p.m.)	Red. (%)	
(*a*) Test No. 1 (Dec. 4, 1950)							
7.40[1]	8.05	210	18.2	85.8	17	95.6	7.85
4.08	4.75	150	68.0	47.3	17	95.6	5.00
5.05	5.50	95	68.4	47.0	26	93.1	5.60
6.04	7.20	200	17.0	86.8	67	82.3	6.88
7.01	7.80	210	16.4	87.3	10	97.4	7.60
8.00	8.09	190	18.6	85.6	16	95.8	7.90
9.05	8.20	195	26.2	79.8	22	94.2	8.00
10.08	9.00	140	62.2	51.7	90	76.1	8.75
(*b*) Test No. 3 (Dec. 6, 1950)							
7.50[1]	8.00	195	12.2	88.6	12	91.4	7.97
4.08	4.43	85	69.0	36.1	—	—	4.50
5.09	5.60	115	67.0	38.0	—	—	5.63
6.00	7.00	140	15.4	85.7	12	91.4	6.88
7.02	7.75	190	13.2	87.8	7	95.0	7.68
8.03	8.03	185	17.0	84.2	11	92.1	8.10
9.00	8.33	150	21.0	80.5	22	84.3	8.36
10.08	9.32	100	42.0	61.1	49	65.0	9.04
(*c*) Test No. 5 (Dec. 8, 1950)							
7.46[1]	8.28	210	11.7	86.6	1	99.3	8.30
4.00	4.25	135	51.0	45.8	67	55.0	4.35
5.03	5.72	140	47.0	50.0	50	66.4	5.80
6.00	6.90	135	16.3	81.9	12	92.0	6.95
7.03	8.00	205	14.3	84.0	3	97.9	8.00
8.00	8.38	190	12.0	86.3	1	99.3	8.38
9.02	8.45	145	13.0	85.4	2	98.6	8.50
10.02	9.30	95	33.0	64.2	19	87.3	9.35
(*d*) Test No. 8 (Dec. 13, 1950)							
7.28[1]	7.60	230	9.7	92.0	3	98.4	7.53
4.00	4.62	145	58.0	51.6	80	57.4	4.80
5.03	5.80	130	24.0	80.0	12	93.6	5.70
6.03	6.68	190	10.3	91.3	5	97.3	6.54
7.00	7.45	220	9.2	92.2	0	100.0	7.40
8.00	7.76	210	10.0	91.7	11	94.2	7.66
9.03	8.00	175	11.4	90.5	10	94.7	7.88
10.03	9.36	105	51.0	57.4	61	67.5	9.30
(*e*) Test No. 10 (Dec. 15, 1950)							
7.52[1]	7.50	290	22.0	80.0	1	99.0	7.36
4.00	4.20	320	65.0	40.8	45	53.1	4.33
5.00	6.00	150	35.0	68.1	8	91.6	5.95
6.05	6.92	235	16.5	84.9	1	99.0	6.76
7.05	7.48	280	16.0	85.4	1	99.0	7.34
8.00	7.75	245	21.0	80.9	1	99.0	7.50
9.03	8.00	195	23.0	79.1	1	99.0	7.80
10.03	9.46	110	60.0	45.4	29	69.8	9.35

[1] Control.

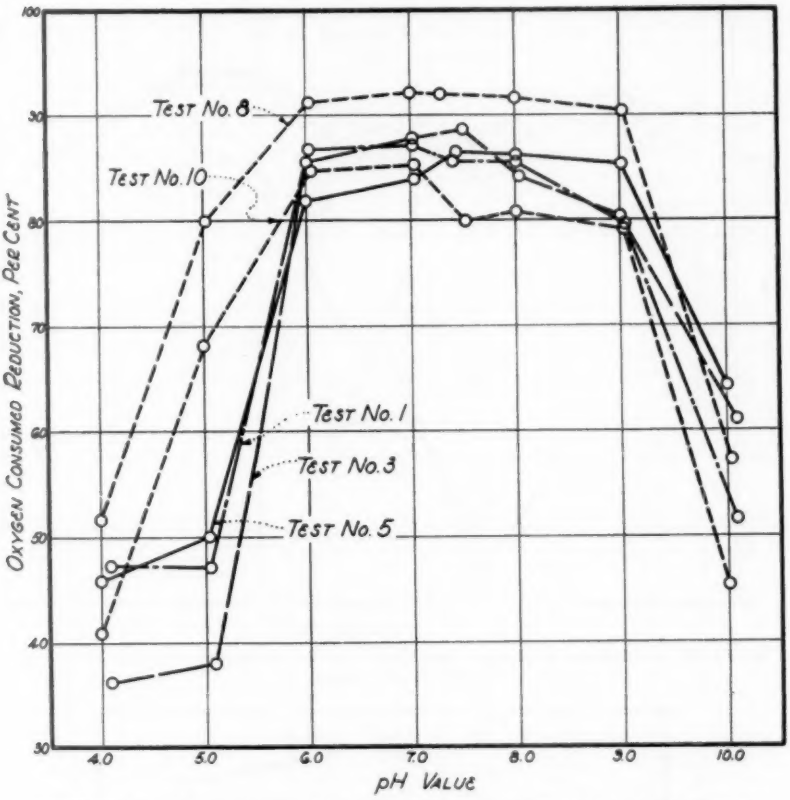

FIGURE 1.—Oxygen consumed reduction by activated sludge process at various pH values.

As indicated in Table II, there was, with one or two exceptions, an increase in the pH value during aeration of those sewage samples that had been acidified and a decrease in those that had been rendered alkaline.

The best results, as judged by the reduction in oxygen consumed, were obtained in the sample in which the pH of the sewage was not adjusted and the one in which the pH was adjusted to 7.0. These reductions, in general, varied from 85 to 90 per cent. At pH values as low as 6.0 and as high as 9.0 the efficiency was only slightly less than at the optimum. Below a pH of 6.0 and above a pH of 9.0 there was a sharp reduction in efficiency. At a pH of 4.0 the average reduction of oxygen consumed for the ten groups of tests was 43.2 per cent.

The percentage removals of suspended solids at the various pH values after 4 hr. of aeration and 2 hr. of quiescent settling are summarized in Figure 3. Each point on the curve is the average of the values corresponding to each pH value. Average reductions exceeded 90 per cent with pH values varying from 6.0 to 9.0. At a pH of 5.0 the reduction averaged 86.9 per cent; at pH 4.0 the reduction was 53.6

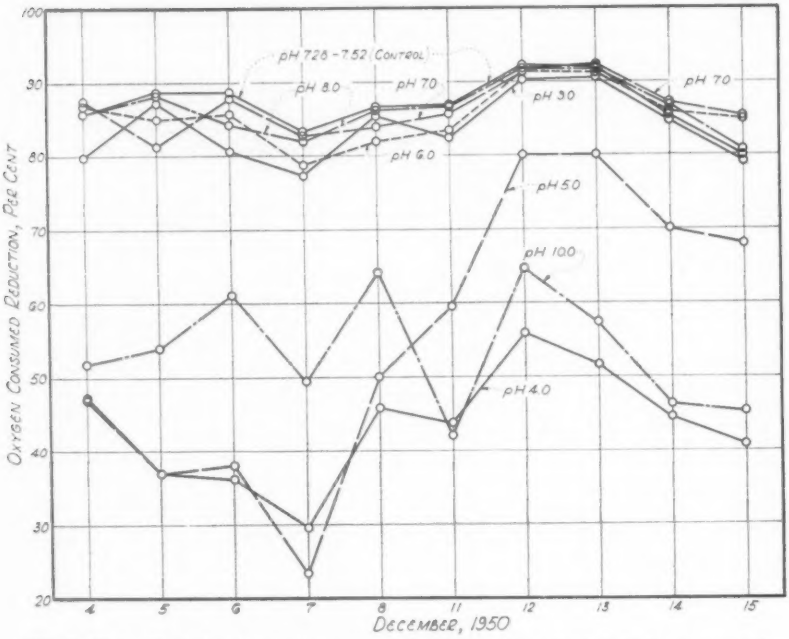

FIGURE 2.—Variation in oxygen consumed reduction by activated sludge process at various pH values.

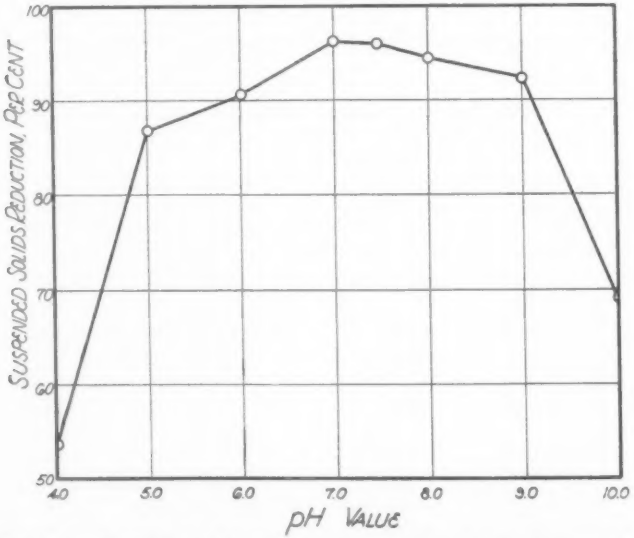

FIGURE 3.—Suspended solids reduction by activated sludge process at various pH values.

TABLE III.—Bacteriological Analyses of Sewage Before and After Aeration (Results Expressed in Thousands)

pH	Influent		Mixed Liquor Before Aeration		Mixed Liquor After Aeration		Effluent	
	Total Count	Coliform Group (M.P.N./ml.)	Total Count	Coliform Group (M.P.N./ml.)	Total Count	Coliform Group (M.P.N./ml.)	Total Count	Coliform Group (M.P.N./ml.)
(a) Test No. 1 (Dec. 4, 1950)								
7.40[1]	520	250	710	250	860	25	36	25
4.08			1,380	250	580	25	231	25
5.05			2,600	2,500	1,920	250	39	25
6.04			3,780	2,500	2,520	250	180	25
7.01			4,820	2,500	8,600	2,500	36	25
8.00			3,360	2,500	1,070	250	27	25
9.05			1,890	250	890	250	19	25
10.08			3,780	2,500	2,940	250	1,260	250
(b) Test No. 3 (Dec. 6, 1950)								
7.50[1]	55	250	1,640	250	1,040	250	9.8	25
4.08			220	25	150	25	78	25
5.09			7,240	2,500	5,250	2,500	1,320	250
6.00			3,150	2,500	1,680	250	12	2.5
7.02			4,160	2,500	3,990	2,500	53	25
8.03			3,150	2,500	2,940	250	8	2.5
9.00			10,400	2,500	4,400	2,500	262	250
10.08			12,200	2,500	7,600	2,500	582	250
(c) Test No. 5 (Dec. 8, 1950)								
7.46[1]	141	25	1,640	250	3,570	2,500	3.3	2.5
4.00			1,440	250	550	250	177	25
5.03			7,100	2,500	4,600	2,500	450	25
6.00			4,700	2,500	5,800	2,500	25.4	2.5
7.03			3,460	2,500	6,100	2,500	25.2	2.5
8.00			5,040	2,500	4,800	2,500	18.9	2.5
9.02			12,600	2,500	640	250	41	2.5
10.02			9,200	2,500	1,320	250	232	25
(d) Test No. 8 (Dec. 13, 1950)								
7.28[1]	1,520	250	2,160	250	2,920	2,500	5.3	2.5
4.00			610	250	1,960	250	6.8	2.5
5.03			3,360	2,500	2,080	250	5.7	2.5
6.03			2 280	250	2,160	250	5.1	2.5
7.00			1,540	250	700	250	10.4	2.5
8.00			990	250	2,440	250	16.2	2.5
9.03			2,240	250	3,200	2,500	18.4	2.5
10.03			2,560	250	4,120	2,500	420	25
(e) Test No. 10 (Dec. 15, 1950)								
7.52[1]	236	25	1,280	250	440	250	9.2	2.5
4.00			1,800	250	230	250	17.4	25
5.00			2,480	250	3,220	2,500	9.6	2.5
6.05			1,640	250	732	250	4.6	2.5
7.05			1,060	250	620	250	5.1	2.5
8.00			1,780	250	630	250	12.6	25
9.03			1,170	250	660	250	12.4	25
10.03			2,280	250	2,240	250	178	25

[1] Control.

per cent. At a pH of 10.0 the reduction averaged 69.1 per cent.

The bacteriological analyses of the sewage before aeration, of the mixed liquor before and after aeration, and of the effluent after settling, are given in Table III. Total counts were run in triplicate at 37° C. using standard nutrient agar. Coliform determinations were made by the Wilson method as modified by Bardsley (11). As is to be expected, the results are quite variable. However, a few generalizations can be made. As a rule, there was a reduction in total count in the mixed liquor after the 4-hr. aeration period. This reduction was particularly pronounced at low pH values. At a pH value of 4.0, both before and after aeration of the mixed liquor, the number of organisms in the coliform group was usually less than in the samples maintained at higher pH values. Adjusting the sewage to a pH value as high as 10.0 apparently did not as a rule reduce the total count or the number of organisms in the coliform group. The reduction in total count after settling for 2 hr. was usually greatest between pH values of 6.0 and 9.0. At both low and high pH values the reduction in total count was less. Fig-

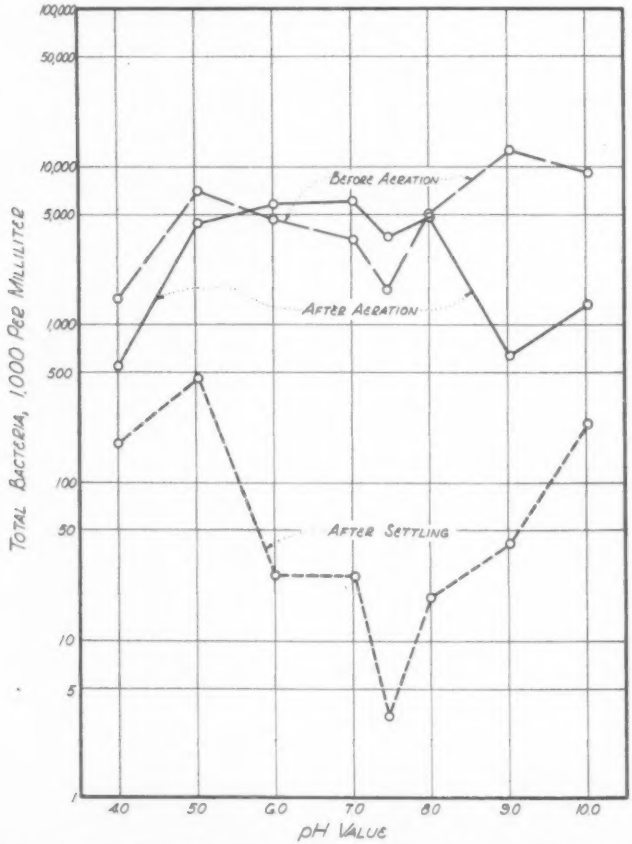

FIGURE 4.—Total bacteria before and after treatment by activated sludge process at various pH values (test No. 5).

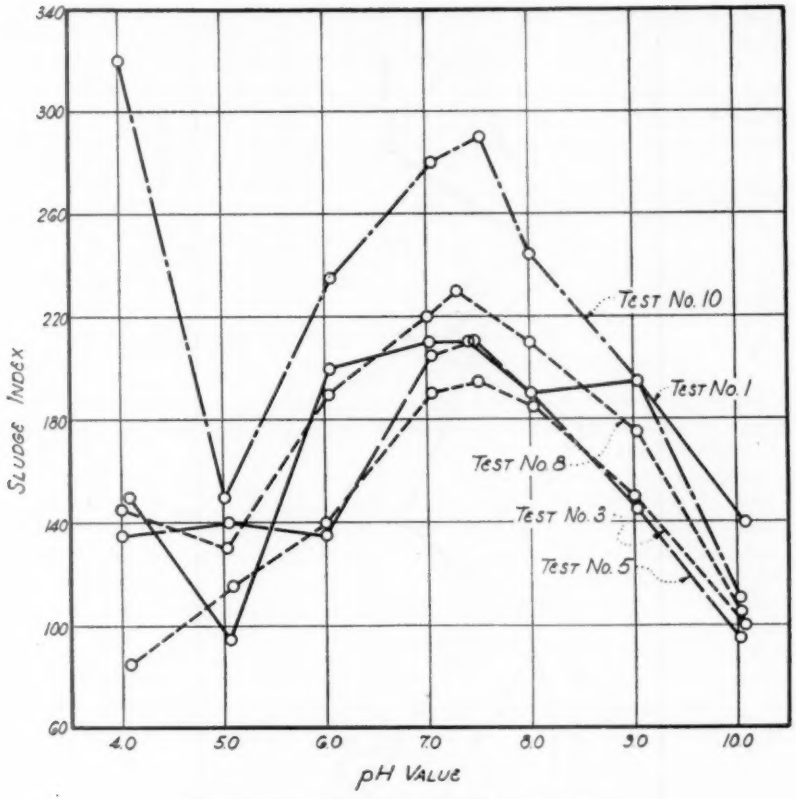

FIGURE 5.—Sludge index at various pH values.

ure 4, which gives the bacteriological analyses during test No. 5, represents, in general, a typical condition.

The sludge indexes of five of the ten tests are shown in Figure 5. Raising or lowering the pH value of the mixed liquor in almost every instance lowered the sludge index. For example, by raising the pH value of the mixed liquor from 7.52 to 10.03 during test No. 10 the sludge index was lowered from 290 to 110. These results indicate the possibilities of controlling sludge bulking by adjusting the pH of the mixed liquor.

An examination of Figure 2 indicates that when the sewage was adjusted to a pH of 5.0 there was an appreciable increase in the removal of oxygen consumed after a few days of operation. The reduction increased from 47.0 per cent at the beginning of the test to 80.0 per cent at the end of 8 days. Because it was possible that the organisms responsible for the purification of the sewage became adjusted to this pH value, a second group of experiments was run for a period of 21 days with the sewage adjusted to pH values of 5.0 and 5.5. As in the previous tests, settled sewage, to which activated sludge was added, was acidified with hydrochloric acid, aerated for 4 hr. and settled quiescently for 2 hr. The results are shown in Figure 6.

On January 16, with the sewage adjusted to a pH value of 5.02, the reduction in oxygen consumed was 48.3

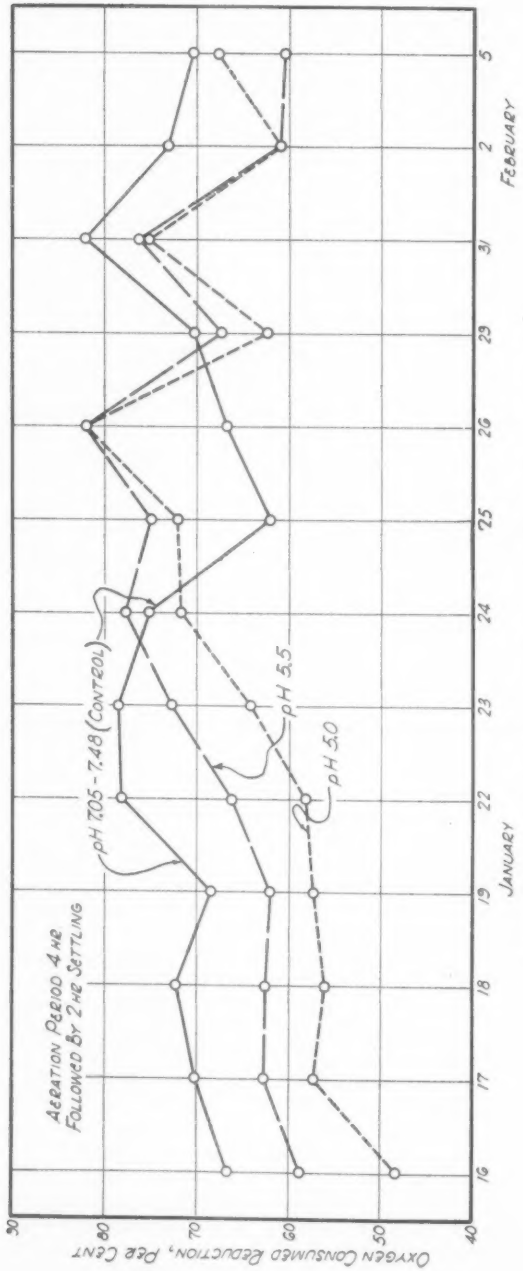

FIGURE 6.—Increase in removal of oxygen consumed; pH 5.0 and 5.5.

per cent. By January 24 the reduction had increased to 64.2 per cent; three days later the reduction reached a maximum of 82.1 per cent. During the 12-day period from January 24 to February 5 the removal of oxygen consumed averaged 70.5 per cent, as compared with removals of 71.5 per cent in the control and 71.4 in the sewage adjusted to a pH of 5.5. In every instance the sludge indexes of the acidified sewages were considerably less than that of the control.

Conclusions

The following conclusions have been formulated from the experiments:

1. The best performance, as judged by the oxygen consumed test, was at a pH of 7.0 to 7.5. Removals were almost as good at pH values ranging from 6.0 to 9.0. Removals averaged approximately 43 per cent at a pH of 4.0 and 54 per cent at a pH of 10.0.

2. Although the percentage removal of oxygen consumed at a pH of 5.0 or 5.5 was considerably less than at pH 7.0 to 7.5 during the first few days of the studies, the removals at these lower pH values were, within about a week, only slightly less than the removals in the control.

3. The removal of suspended solids was greatest at a pH between 6.0 and 9.0. Optimum removal occurred at a pH of 7.0 to 7.5.

4. The reduction of total bacteria was greatest at pH values between 6.0 and 9.0.

5. Raising or lowering the pH on either side of neutrality greatly reduced the sludge index.

Acknowledgments

The Back River sewage treatment works, where the experiments were conducted, are under the general direction of P. L. Holland, director, Department of Public Works, with John J. Hunt, sewerage engineer. Dr. Abel Wolman is consultant to the Department of Public Works. R. J. Trautman, principal associate engineer, has direct supervision of the sewage works and Paul L. Smith is plant superintendent. The bacteriological work was done by Hester Hatch, senior bacteriologist.

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CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL *

VI. APPLICATION OF RESULTS

By Willem Rudolfs, Lloyd L. Falk, and Robert A. Ragotzkie

The use of human excreta for fertilizer, ranging from night soil application to irrigation with sewage or polluted river water, is a world-wide practice. Although "advanced" hygienic western civilizations deplore the night soil practices, the economy of densely populated areas in large sections of the world would be wrecked without human manure. The wastage of organic and inorganic fertilizer by modern municipal sanitary practice, which discharges sewage or sewage effluents into streams and sends sludge to sea or burns it, has been subject to frequent discussion and attack. In many instances sewage and sludge are utilized and at many places where water is scarce in this country, settled sewage is used for irrigation or to augment the available water for this purpose.

Aside from aesthetic reasons, the principal objection to soil fertilization with human waste products and use of polluted water for irrigation has been the potentiality of transmission of human bacterial diseases through the consumption of raw vegetables grown in soil fertilized by sewage sludge or irrigated with polluted water. This question has been of concern to public health officials and others for many years.

In addition to the conservation aspect of the problem, there is a military one. In the supply of troops in remote or distant parts of the world, fresh, raw food is of importance for the proper maintenance of personnel health. Occupation or expeditionary forces in lands where night soil practices are the rule must be supplied with vegetables from known "safe" areas. Troops, as well as travellers, are cautioned against eating anything raw in countries of low sanitary standards. Even if night soil fertilization practices were stopped on certain tracts of land, how long would it be before crops could be grown with reasonable assurance that they would be bacteriologically safe for raw consumption, or at least as safe as crops grown under similar conditions in the sanitation-minded, human-manureless countries? What is the length of the survival time of enteric bacterial and animal pathogenic or parasitic organisms where soil is poluted or human waste is applied to the soil in the form of sludge or polluted water for growth of crops? Which factors are of importance in contamination of vegetables grown in polluted soil or vegetables subject to polluted irrigation water? Are there methods whereby vegetables of questionable origin can be rendered safe for raw consumption and, if so, what is the best, simplest, and cheapest?

In an effort to supply at least partial answers to these questions, studies were made with tomatoes, lettuce, spinach, and carrots grown in soil receiving sewage irrigation and artificially contaminated with suspensions of *E. coli*, *Salmonella*, *Shigella*, *Endamoeba histolytica*, *Ascaris* eggs, and feces.

Coliform Organisms

The coliform group of bacteria has been extensively and successfully used

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to test the sanitization of water supplies, sewage disposal, and stream purification. Although these organisms are not always of human enteric origin, they are indicative of contamination by human or animal fecal wastes, show greater resistance to external environmental conditions than pathogens, and their numbers are relatively easily determined. Hence, they were used as indicator organisms in the vegetable contamination studies.

Various types of vegetables have been used in previous contamination and decontamination studies, including radishes as a root crop, lettuce as a green vegetable, and watercress, which may be grown in polluted water. In the present investigations a large amount of work was done with tomatoes. This is one of the more common vegetables eaten raw, matures at various distances from the ground, which allows demonstration of the effects of variation of the contamination with height, grows exposed to the atmosphere subject to various intensities of sunlight, and has a waxy surface, which may prolong survival of organisms or make wetting and decontamination difficult.

Carrots were chosen as a subsurface growing crop frequently eaten raw. They have a rough surface, but are fairly easily wetted, allowing dirt to be removed. For a green vegetable, lettuce was selected because it grows close to the ground. Although the leaves have a wrinkled surface, which may harbor dirt and organisms, it is the usual practice to discard the outer leaves. In addition, experiments were made with spinach, which usually contains sand and is frequently prewashed before use. As this vegetable is rarely eaten raw it was used primarily in conjunction with decontamination experiments.

Previous methods used for evaluation of enteric or other bacteria on the surface of vegetables have generally involved washing the vegetables in sterile water or crushing them by hand and using the expressed liquors. Bacteria found in the washings or liquors were considered as those originally on the vegetable surface. These methods may indicate comparatively slight infection or with a particular decontamination process may give apparent excellent bacterial reductions, but it is conceivable that residual bacteria are so tenaciously held and protected that they are not determined in the washings or juices.

Experiments show that even after field-grown vegetables are washed with continuous vigorous agitation for as long as 15 min. the numbers of organisms remaining on tomatoes are essentially the same as on the unwashed fruit. For this and other reasons, the preparation for assays included the maceration of whole vegetables in a Waring blender. Although this preparation may not allow measuring all the organisms on a vegetable surface, it is believed that the results will more closely approximate this number than those obtained with any previously described method of preparation. First, the maceration occurs at such high speed that bacterial clumps would tend to break into smaller clumps or even into individual organisms. Second, some of the organisms adhering tenaciously to the vegetable surface may be transferred to the liquid phase. Third, the vegetable surface is finely divided by the maceration, resulting in its serial dilution together with the liquid phase in the counting technique, and the organisms adhering to the macerated vegetable surface are more closely approximated.

The absence of coliform organisms, even from unpolluted soils, is almost impossible to demonstrate, although claims have been made that they are absent in most virgin soils. Ordinary farm soils may contain large numbers of coliform organisms. Results obtained during other laboratory experimentation show that the numbers

of coliform organisms on a sandy soil truck farm varied from 1,300 to 7,000 per gram of soil.

Vegetables grown under ordinary farming conditions may be expected to contain coliform organisms. This was the case with tomatoes grown in soil where no recent gross pollution was present. The numbers of coliform organisms varied from 1 to 37,000 per gram of tomato. Tomatoes grown in soil which had never received sewage polluted material contained 1 to 48,000 organisms per gram, and tomatoes bought in the open market repeatedly showed similar numbers of coliform organisms, no matter whether the tomatoes were bought during the winter or summer months.

The important point is that vegetables grown under known conditions in the absence of sewage pollution contain numbers of coliform organisms and are consumed raw over the entire country. No one hesitates to eat them, and so far as is known no epidemics of bacterial diseases have resulted from their consumption. It is also well-known that vegetables grown on sewage farms have been and are consumed raw without presumably causing epidemics of enteric bacterial diseases. It would seem that if vegetables grown under farm conditions, but fertilized with human waste products, such as sewage, polluted stream water, sewage sludge, or even direct application of fecal matter or night soil, show no higher average coliform contamination when harvested than do farm-grown vegetables fertilized with barnyard manure or artificial fertilizer; the danger to the public health through the consumption of such vegetables, from the bacteriological point of view, would probably be not greater than that from vegetables grown ordinarily on the farm.

The problem of the use of soils which have received previous fertilization with human wastes for the growth of vegetables for raw consumption is of concern not only where night soil application has been practiced, but also where the use of sewage sludge from modern treatment plants is contemplated. The results obtained on plats receiving concurrent sewage irrigation, previous sewage irrigation, and soil never sewage irrigated are of particular interest. For comparison, the figures for coliform organisms present on tomatoes resting on the ground, which would presumably be subject to the greatest degree of contamination, are perhaps of greatest interest, but results of tomatoes grown at different distances from the ground are included (Table I). The over-all average coliform concentration on tomatoes grown in area B, where the land had been frequently flooded with sewage up to the time of planting, was no higher than on tomatoes grown in area C, which had never been subject to sewage irrigation. The tomatoes grown on area B would be considered bacteriologically to be no more dangerous to eat raw than those from area C. If the land were fertilized with sewage sludge before the crop was planted, it may be assumed that the danger to health from eating such crops would be practically non-existent.

TABLE I.—Coliform Contamination of Normal Tomatoes Grown on Polluted and Unpolluted Experimental Plats Operated under Normal Farming Conditions

Area	Type of Sewage Irrig.	Distance from Ground (in.)	Coliforms per Gram	
			Median	Range
A	Concurrent	0	110	1 to 45,000
		0.5 to 5	7	1 to 50,000
		6 to 10	8 to 9	1 to 720
		12 to 34	6 to 14	1 to 330
B	Previous	0	3	1 to 300
		1 to 5	7	1 to 36,000
		6 to 10	12	1 to 750
		13 to 30	30	1 to 300
C	None	0	6 to 27	1 to 50
		0.5	2	1 to 60
		6 to 10	6 to 200	1 to 530
		12 to 26	17	1 to 8,400

If the flooding with sewage immediately before the plants were set is considered comparable to the plowing-in of sewage sludge before planting there would be no need for a waiting period between application of the sludge to a soil and the setting of plants. In other words, sewage sludge could be plowed under in spring as well as in fall.

When the problem of the use of material which contaminates the soil during growth of plants is considered, the results obtained on tomatoes grown on area A, which had received continual irrigation with settled sewage, are of particular interest. The average median coliform contamination on normal tomatoes grown in area A was 9 per gram, or no higher than when tomatoes were grown in the unpolluted area C (10 per gram).

It would be expected that tomatoes with abnormal stem ends (the presence of splits and grooves radiating from the stem ends) grown on polluted soil would have higher coliform concentrations than those grown on unpolluted soil. Actually, the average coliform concentration of such tomatoes grown on area A (polluted) was 120 per gram, as compared to 44 coliforms per gram of similar tomatoes grown in area C (unpolluted). Both groups showed considerably higher and more widely fluctuating numbers of coliform organisms than the normal tomatoes. The difference from normal tomatoes was probably the result of protection afforded by the cracks on the abnormal tomatoes. The difference between abnormal tomatoes grown in polluted and unpolluted soil is one of degree or extent of contamination. As the normal fruit in these areas showed no appreciable differences and the unsightly and unappetizing portions of the stem ends would normally be cut away before eating, it is felt that the tomatoes grown in polluted soil would be no more dangerous, bacteriologically, than those harvested from normally farmed soil.

The discussion thus far has been concerned with crops grown under conditions of irrigation water flowing on the surface of the soil. What are the potentialities of bacterial contamination when overhead irrigation is practiced with polluted water or when night soil or sewage raw sludge is applied and the material adheres and dries on the edible parts of the plants? Results show that tomatoes receiving periodic sprays of feces or *E. coli* suspensions had considerably higher coliform concentrations 11 days after the last spraying than were found for normal and abnormal plants with deep-grooved stem ends. However, 35 days after spraying had been discontinued there was no indication of an appreciable difference between the coliform contamination on the sprayed and unsprayed tomatoes. After 42 days no difference could be found. Hence, spraying should be discontinued at least a month before harvesting.

Salmonella and *Shigella*

Most of the enteric diseases of man are known to be caused by bacteria of three genera of the family *Enterobacteriaceae*. These so-called pathogenic genera are *Salmonella* (paratyphoid), *Eberthella* (typhoid), and *Shigella* (dysentery). Because these bacteria are regularly found in sewage and sewage-polluted water, representative species of *Salmonella* and *Shigella* genera were used in the studies of their survival on vegetables.

Experiments showed that *Salmonella cerro* suspensions sprayed on tomatoes survived longer under laboratory conditions than under field conditions. This is illustrated in Figure 1, which shows that the organisms sprayed on tomatoes growing in the field survived less than 4 days, whereas under laboratory conditions the organisms survived for more than 20 days. The longer survival of *Salmonella* in the laboratory is attributed to the uniformity of temperature and

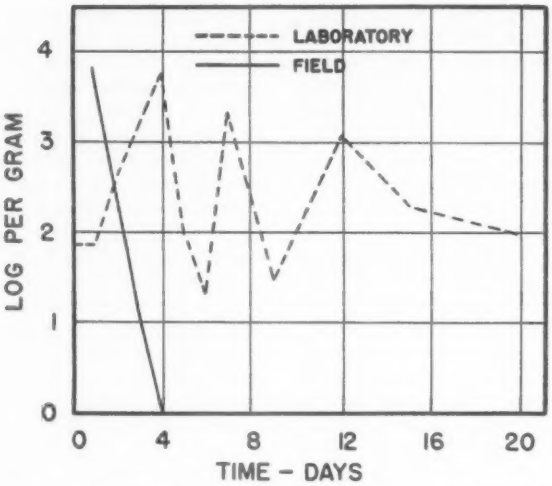

FIGURE 1.—Survival of *Salmonella cerro* on tomatoes in laboratory and field.

humidity and to the absence of direct sunlight. In the field, the bacteria exhibited a logarithmic death rate.

The effect of temperature on the bacterial death rates in the field is illustrated in Figure 2. The death rates of *Shigella alkalescens* at average temperatures of 82° and 69° F. were high, as demonstrated by the slope of the lines. At these temperatures, all organisms had disappeared after 1 and 2 days, respectively; it required 4 days at a temperature of 62° F.

The effect of rain on the persistence of contamination is difficult to estimate, but on the basis of the washing experiments, it is doubtful whether rain removes an appreciable number of the bacteria from the vegetables. It is more likely that rain would tend to increase the survival time by increasing the relative humidity, decreasing the temperature, and adding new contamination by splattering.

The effect of direct sunlight, known to be bactericidal in action, was minimized in all experiments by spraying only well-shaded tomatoes, so that crops in the field could not be decontaminated completely by this factor.

The death rate of *Shigella* and *Salmonella* in the field was found to be independent of the initial concentration, but the time required for complete decontamination was increased by higher initial concentration of bacteria. Nevertheless, with even excessively high concentrations the organisms could not be recovered after less than one week. In comparison with the survival of coliforms, the pathogenic organisms disappeared first.

Endamoeba Histolytica

In the survival of the protozoan cyst of *E. histolytica* the most important factor is desiccation. The cysts die within 5 min. after drying. When they are kept in a suitable solution and stored at 10° C. they may survive for 6 to 7 days, a period that probably approaches the normal life span of the cysts. In the field, a maximum survival of 18 hr. was found. Survival time in the field on leaf lettuce was slightly longer than in cracks of tomatoes, but less than underneath tomatoes that were resting on damp soil; however, when the soil was dry the survival time was less than 18 hr.

In the case of low crops, such as lettuce, celery, and parsley, the conventional ridge and furrow technique of cultivation lessens the chances of survival.

The dangers involved in soil pollution with respect to *E. histolytica* are of much shorter duration than those dangers stemming from bacterial contamination. Under field conditions, survival of *E. histolytica* would be less than 3 days. It may be assumed that under all conditions a period of 10 days would be enough to exceed survival time of the cysts.

Ascaris Eggs

Where the incidence of helminth parasites is great and human excreta is used as fertilizer or irrigation, there is a possibility that helminth eggs in varying stages of development may reach and adhere to edible parts of the growing plants. In view of the resistance of eggs of the *Ascaris* worm to external conditions, it may be expected that their survival on vegetables in the field may be for considerable periods.

It is known that relative humidities below 75 per cent are lethal to these eggs, particularly for the less resistant varieties. However, at the surfaces of vegetables exposed to varying atmospheric conditions higher humidity values are likely to be present a considerable part of the time. The eggs are comparatively rapidly killed in soil exposed to the sun. The field experiments conducted on the survival of *Ascaris* eggs deposited on tomato and lettuce surfaces showed that some eggs were still present more than one month after application. Although

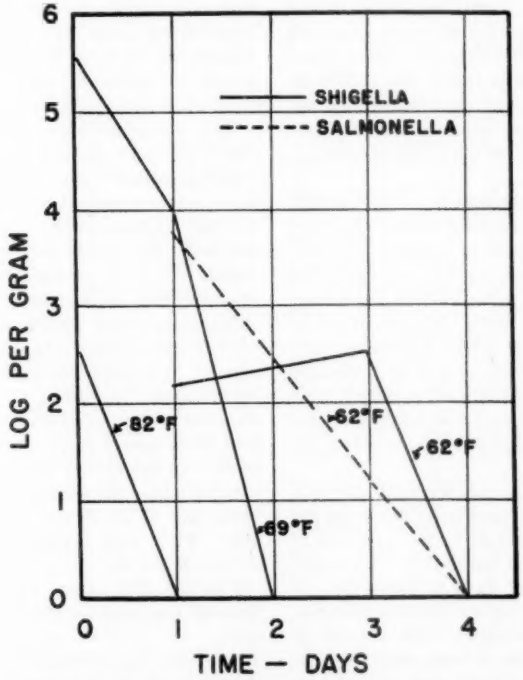

FIGURE 2.—Survival of *Shigella* and *Salmonella* in the field.

some eggs remained on the vegetable surface for this period of time, their development was retarded. When unicellular eggs were used in the field, no eggs developed to the mature motile embryo stage. It is the latter stage which is infective to the host. It would appear that a period of one month between application of fecal matter to exposed plants, such as tomatoes and lettuce, and the harvesting of these vegetables would greatly diminish the hazards of helminth infection from consumption of the raw vegetables.

Desiccation is one of the principal lethal factors against helminth eggs and it is possible that their survival time under moist tropical conditions is longer than in a dryer temperate zone.

Decontamination

When fecal matter is directly applied to edible parts, vegetables should not be harvested for at least one month after the last application. Even when this precaution is taken, the foodstuffs may be harvested or handled by unsanitary persons or carries. Therefore, there still may be need for decontamination.

For decontamination to be worthwhile, it must not only reduce the average contamination of a group of vegetables to a low value, but also the range of the contamination remaining from vegetable to vegetable must not be great. In other words, if several vegetables in a group escape a particular method of decontamination with a comparatively high bacterial concentration, the method cannot be considered reliable.

The results have shown that bacteria, protozoan cysts, and helminth eggs are tenaciously attached to the surfaces of vegetables. The possibility of storage for a number of days to allow the organisms to die did not appear feasible. This is in conformity with results of earlier unpublished laboratory experiments conducted with root crops, such as carrots and beets, and vegetables, such as celery and cabbage, grown under ordinary farming practice in sewage-irrigated soil and in soil fertilized with barnyard manure followed by normal storage practice at the farm. The results obtained showed essentially the same pattern as the results for short storage times under controlled conditions. There were large fluctuations in coliform numbers, from sample to sample, over a period of several months without a tendency of material reduction in the numbers of organisms. Incidentally, no consistent difference between the number of coliform organisms present could be found between the crops grown in sewage-irrigated and those grown in manured soil.

Washing with plain water was completely ineffective for removing bacteria or *Ascaris* eggs. It is interesting to note that the rinsing of raw vegetables under the tap, as practiced by the average housewife, except for the removal of gross dirt, if present, accomplishes little so far as bacterial removal is concerned. Its value, apparently, is mostly psychological.

The use of detergents as an aid in removing bacteria has about the same value as water. Dirt particles may be more easily removed by these methods, but the bacteria on the surface are untouched. The cationic agents have been widely used in sanitization of eating utensils, but the bacteria on vegetable surfaces are not appreciably affected by the germicidal properties of these agents. The tenacity with which these bacteria on vegetable surfaces resist physical removal and the action of these sanitizing agents is apparently directly related to the ability of the bacteria to survive under the conditions of extreme variations of environment found in the field. They may actually be buried in or enveloped by the outer waxy coating on the skin or else be protected by films of material on the vegetable surface.

The use of materials of a germicidal nature, such as chlorine and its compounds, requires high doses to give ef-

fective results. Even so, every member of a group of vegetables cannot be expected to exhibit low coliform residuals. Some will escape with high residuals. Other types of disinfectant might have been considered, but many drawbacks exist. These include impartation of tastes and odors, if such materials as phenolic compounds were used, or the danger to the consumer if mercury or other heavy metal salts were used.

The helminth organisms, such as *Ascaris* eggs, on a vegetable surface would probably be unharmed by any of the killing agents which could be reasonably used for vegetable decontamination. Although the cationic detergents have no toxic effect on the eggs of *Ascaris,* they are effective in removing the eggs from the smooth tomato surface. But 100 per cent removal is not always effected. In the absence of information, one can only assume that one ingested egg will yield one adult worm in the host. Therefore, 100 per cent decontamination of vegetables with respect to helminths may prove mandatory. This should be compared with Kehr and Butterfield's (1) estimate that only 1 to 2 per cent of typhoid organisms ingested actually cause the disease.

If such rigid requirements with respect to helminth eggs or even bacteria are necessary for decontamination standards, even chemical disinfectants obviously cannot be expected to meet them. The results of this work have indicated that the only reliable method for vegetable decontamination is the use of heat. Dipping of vegetables in boiling water results in scalding and wilting. Such a high temperature of the water is not required for effective decontamination. If there is doubt about the sanitary quality of the vegetables, soaking them for 5 min. in water at 60° C., which may be considered a form of pasteurization, assures a product of safe quality.

The contamination and decontamination studies reported were primarily conducted with tomatoes and lettuce. Objections can be raised when the results are applied to root crops, such as carrots or radishes, because these are in more intimate contact with polluted soil and are not subject to such large temperature and moisture fluctuations as the edible plant portion growing above ground. In addition, the vegetable surfaces of root crops are more readily wetted and, possibly more readily contaminated. Decontamination, however, may be easier because of their wetability, and they could be readily "pasteurized."

The need for additional work on these other types of vegetables is recognized, but chances are that differences will be only in the degree of contamination. The environment of soil for human bacterial pathogens is so unfavorable that the structure of the plant or its position in the soil would not materially change the danger of disease transmission.

General Conclusions

On the basis of the studies, the following general conclusions are drawn:

1. No evidence has been found that pollutional bacteria, amoeba, or helminth eggs penetrate healthy, unbroken surfaces of vegetables or cause internal contamination.

2. Vegetables to be eaten raw can be grown without health hazard in soils that have been subject to sewage irrigation, night soil application, or polluted stream water irrigation in years prior to the season in which the vegetables are grown.

3. Vegetables grown under conditions of surface sewage irrigation show no higher coliform concentrations than those grown on normally farmed soil, whether sewage was applied before the plants were set or while the plants were growing.

4. If sewage sludges or night soil are applied on the soil surface, or sewage effluents are applied by overhead irrigation during growth of vegetables, such an application should be stopped

at least one month before harvest. If this precaution is taken, the crop will show no higher bacterial contamination than when farmyard manure or artificial fertilizers are applied.

5. Strains of *Salmonella* and *Shigella* do not survive on vegetable surfaces for more than one week. Hence, conclusions based upon coliform contamination offer a considerable margin of safety.

6. Bacteria applied to vegetable surfaces are tenaciously held and protected from the external environment. This permits their survival under field conditions and explains the difficulty of their removal by various types of washes or kill by germicides.

7. The resistance of cysts of *Endamoeba histolytica* to the external environment depends almost entirely on the amount of moisture present. Death of the cysts occurs immediately upon desiccation.

8. During dry periods, cysts of *E. histolytica* survive less than 3 days on vegetables growing above ground in the field. To reduce the danger of transmitting amoebic dysentery through crop contamination to a minimum, the last application of contaminating matter to the soil before harvesting should be at least one week in the temperate zone and two weeks in the wetter climates of tropical regions.

9. Eggs of *Ascaris suum* were recovered in reduced numbers from vegetables one month after application, but all had degenerated, and no completely developed eggs were found on plants in the field. The possible dangers of the transmission of *Ascaris* are greatly reduced if fecal matter fertilization is stopped one month before harvest.

10. Storage, washing of vegetables in plain water, or washing with various detergents, including anionic, nonionic, and cationic compounds, are ineffective as means of bacteriological decontamination.

11. Germicidal rinses of chlorine and its compounds are superior to water and detergents for bacterial decontamination, but are unreliable.

12. Water, anionic, most nonionic detergents, and chlorinated compounds are not effective decontaminants for helminth eggs; cationic detergents aid in removal of eggs from vegetable surfaces. The eggs are resistant to the killing effects of disinfectants which could be used in vegetable decontamination.

13. The only reliably effective method for decontamination of bacterial, amoebic, and helminthic organisms is pasteurization at 60° C. for 5 min.

Acknowledgment

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Industrial Wastes

EFFECT OF METAL WASTES ON SEWAGE TREATMENT PLANT DESIGN AT WATERBURY, CONN.*

By Robert D. Mitchell, James G. Cassanos, and Daniel A. Okun

Respectively, Associate Engineer, Malcolm Pirnie Engineers; Assistant Engineer, Bureau of Engineering, Waterbury, Conn.; and Associate Engineer, Malcolm Pirnie Engineers, New York, N. Y.

For many years the Naugatuck River Valley has contained one of the important industrial developments of the nation. From Torrington on its upper reaches to its confluence with the Housatonic at Derby-Shelton (Figure 1), its cities are industrialized. The copper and brass industry in the United States grew up on this river and many years ago the valley became known as the copper and brass center of the world. Metalworking industries are located at Torrington, Thomaston, Oakville, Waterbury, Naugatuck, Beacon Falls, Seymour, Ansonia, Derby, and Shelton. Naugatuck has become an important rubber center, and Torrington, Watertown, and Derby have developed extensive textile works.

From the beginning of industrialization, the river furnished power, cooling and process water, and a means for waste disposal. As a source of power it has become relatively unimportant in recent years, but its waters have retained their importance for other uses. The river flows through a narrow, steep, and rugged valley with a fall of approximately 13.5 ft. per mile. Its bed is irregular, with gravel and rock formations causing numerous shoals and rapids. Many mill ponds intercept its course and act as settling basins for suspended solids, which in summer, when stream flows are low, become septic and create nuisance conditions.

The average flow in the river during the summer and early fall provides insufficient dilution of the sewage and industrial wastes, and objectionable conditions occur. In winter and spring, higher flows tend to flush out many of the solids accumulated during low flow periods.

These conditions have existed for many years and, although esthetically undesirable, have caused less objectionable conditions than might be expected. Industrial wastes have contributed such a quantity of copper, chromium, and other metal wastes to the river that, to a degree, biological growth has been inhibited. As an example, during one period of 5 hr. the Naugatuck River at Waterbury had a pH of about 4.0 and averaged about 12.5 p.p.m. copper. Furthermore, in several localities, air pollution from industrial processes is of sufficient magnitude to render odors from decomposition in the stream less noticeable.

Historical

As long as 50 years ago, agitation to improve river conditions was current. In 1905–06 Waterbury operated a sewage testing station to determine the character of the sewage. Even at that time the eventual necessity of treatment

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FIGURE 1.—Municipalities of the Naugatuck River Valley, Conn.

was realized and sewers were designed with the idea of ultimate treatment in mind. About 1905 a main intercepting sewer was designed, and shortly thereafter built, to carry the major portion of the city's sewage to a disposal site along the Naugatuck River, where substructures were built for a sewage treatment plant. Considerable work was done on the design of a plant at that time, but for various reasons it was not built.

The first extensive study of records devoted to the pollution of the river as a whole was made in the 1918–21 period when the Industrial Wastes Board of the Connecticut State Health Department made investigations and published a comprehensive report (1). The Board studied such diverse methods of solving the industrial and domestic wastes problem as construction of separate treatment plants at each community, storage of water to increase dilution of waste during flow periods, construction of a Naugatuck Valley trunk sewer to discharge raw or treated sewage into Long Island Sound, and pumping raw or treated sewage over the divide into another watershed. The Board concluded that only treatment at each community was practicable. Significantly, the report stated that:

"1. It will never be practicable to restore the Naugatuck River to a state even approaching its original condition as a potable stream. It must always be the main drain for a populous industrial valley, and, therefore, considerably polluted. However, many of the objectionable features which now exist can be remedied by proper treatment of the wastes at their sources.

"2. Considerable latitude may be exercised in selecting the type and degree of treatment best adapted to different localities, but some method of treatment should be adopted for each of the larger towns.

"3. Industrial wastes should be separated into different classes and a type of treatment determined which is best suited to each class.

"4. For the reason that it is impracticable to attempt to restore the Naugatuck River to its original condition, it does not seem wise to insist on high purification of certain effluents."

During the years following, the State Health Department and the State Water Commission continued their efforts to improve the river. Local cooperation was not lacking, but was hampered by the fact that many cities were bonded to their statutory limits. In 1925, Watertown, located on a small tributary, built treatment facilities for part of its area to improve local conditions. The first main river sewage treatment plant was built in 1939, when Torrington put its plant into operation. In 1943, Waterbury engaged a consulting engineering firm to study and report on sewage treatment facilities for the city. A plant was designed, but the war delayed the start of construction until 1950; it will be com-

pleted in 1951. A number of other towns in the valley have had plans prepared for the treatment of their sewage, including Thomaston, Naugatuck, Ansonia, and Shelton.

Industrial Waste Problem in Waterbury

Waterbury is an important center of the brass industry in Connecticut, a state which manufactures about one-third of the brass and copper products in the United States (2). In addition to three large brass and copper mills, there are more than 100 smaller plants that use acid and alkaline solutions in the cleaning, pickling, plating, and finishing of metal goods. In 1949 these industries consumed 35 per cent of the total metered water from the municipal supply. The plants situated along the rivers also use large quantities of river water, most of which is returned to its source.

The industries located near rivers and brooks, including all the large brass mills, have largely excluded their industrial wastes from the sanitary sewers and are discharging them into adjacent waterways, which eventually reach the Naugatuck River. Most of the smaller plants, however, are situated in densely populated sections of the city with no access to natural watercourses and with only limited space for the installation of treatment facilities. The city sewers provide a convenient outlet for the wastes of these plants.

Wastes from the metal processing industries are of two types—dilute rinse waters that are discharged continuously from cleaning, pickling, bright dip, or plating operations; and concentrated spent pickle baths or plating solutions that are dumped intermittently. In a detailed investigation of the wastes from the pickling operations at one of the large copper and brass plants of the state, the Connecticut State Water Commission (3) found that the dilute wash waters carry away 88 per cent of the acid used and 90 per cent of the lost metals. Studies of other operations in the industry would probably also show that the rinse waters carry off most of the acid and metals.

Initial studies into the nature of wastes at Waterbury in 1944 indicated the presence of considerable amounts of copper in the sewage, but indications were that most of it came from an industrial section along the Mad River (Figure 2) in which industries were discharging their wastes to the municipal sewers, which were already inadequate for sanitary sewage alone. The engineers' report to the city recommended construction of a primary sewage treatment plant on the Naugatuck River below the city. Digestion of sludge was recommended, based on a program of excluding industrial wastes from the sewers. It was believed that much of the industrial waste was contributed by industries on the Mad River and construction of a new intercepting sewer along this river for sanitary sewage alone would materially improve conditions.

Plans were submitted to the city with the recommendation (a) that the Mad River interceptor be built; (b) that trade wastes be excluded from the sewer system; and (c) that further studies be made before a contract for construction of the sewage treatment plant was let. The State Health Department approved these plans, subject to further study of the metal waste problem.

The Board of Aldermen soon enacted an industrial waste ordinance, which gave the city the power to exclude from the sewers any waste deemed undesirable for sewage treatment or the sewer system.

On January 13, 1949, the State Water Commission ordered the city to call for bids on the sewage treatment plant on or before July 1, 1949. It also requested submission to the State Health Department of a review report on the treatment plant design prior to calling

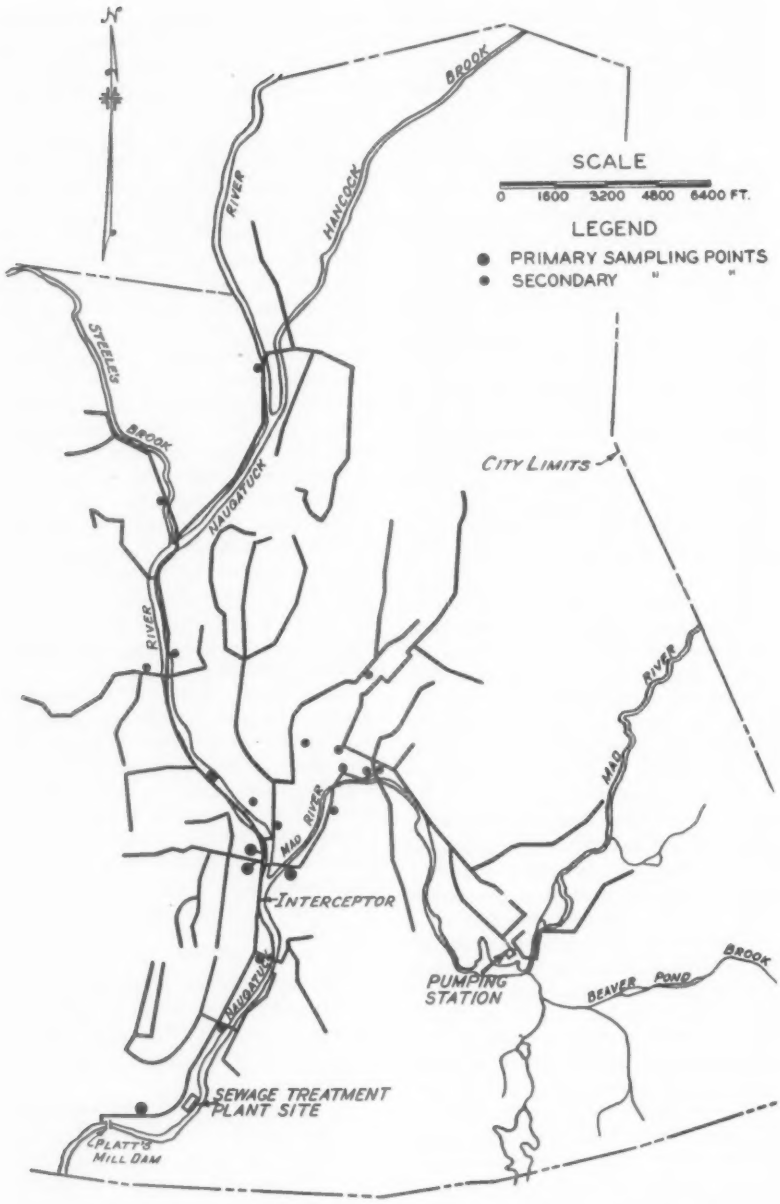

FIGURE 2.—Map of Waterbury, Conn., showing existing trunk sewers and sampling points.

for bids. It further ordered the city to advertise for bids for the construction of portions of the Mad River sewer on or before April 1, 1949.

The balance of this paper describes the investigations required for the review report, which was submitted to the State Health Department on April 30, 1949.

Investigation into Effect of Heavy Metals and Acidity on Sewage Treatment

Waterbury's industries use copper, zinc, chromium, nickel, iron, aluminum, and smaller quantities of other metals. Of these, copper and chromium are the most important. Rinse waters from pickling and bright dip operations and many plating solutions are acidic, whereas other plating solutions are alkaline and may contain cyanides.

Acid wastes, unless diluted by sufficient quantities of domestic sewage in the receiving sewer, may cause serious disintegration of the sewer system, especially where, as in Waterbury, trunk sewers are built of concrete. Sewage plant structures will be similarly affected. Because the municipal water supply of Waterbury is relatively soft (about 20 p.p.m. alkalinity as $CaCO_3$), the neutralizing capacity of the domestic sewage is also low. Highly alkaline wastes tend to precipitate metals that might otherwise be carried in solution. There is a difference of opinion with regard to permissible pH range of industrial wastes discharged to public sewers. The most authoritative statement appears to be in the manual on "Municipal Sewer Ordinances" (4), which suggests a permissible range of pH 5.5 to pH 9.0.

The finding of substantial quantities of copper in sewage at New Haven and its possible effect on sewage treatment processes was discussed by Mohlman (5) in 1917. However, little data on the actual effect of metal wastes on sewage treatment were published prior to 1940. Among the earlier workers was Hoover, whose early results were published in the Eighth Biennial Report (1938–40) of the Connecticut State Water Commission (6). He found that 0.5 p.p.m. of copper in sewage produced a sludge containing over 100 p.p.m. and concluded that "when the amount of copper in sewage exceeds 1 p.p.m., a decrease in the efficiency of digestion will be noted."

He also found that when 200 p.p.m. of precipitated chromium is present in sludge the rate of digestion is noticeably reduced and when the concentration of chromium in sewage consistently exceeds 1 p.p.m., its effect is similar to that of copper.

In 1941, Rudgal (7) reported a concentration of 3,000 p.p.m. of copper in the bottom of the digestion tanks at Kenosha, Wis., with daily additions of raw sludge containing 50 to 100 p.p.m. of copper. He confirmed the toxic effect of copper by bottle tests and concluded that digestion would stop at a copper concentration in the digester of about 200 p.p.m. Rudgal (8) later showed that 0.7 p.p.m. of copper in the raw sewage concentrated to 226 p.p.m. in the raw sludge on the wet basis and to 3,710 p.p.m. on a dry basis. In the digesters, the copper concentration reached 5,000 p.p.m. on a wet basis, and 50,000 p.p.m. on a dry solids basis, and no gas was produced.

The difficulties reported at Kenosha were traced to copper-bearing wastes from a large copper and brass plant with operations similar to those existing in Waterbury. When the digesters were started in August 1940, gas production was very poor and continued low until copper wastes were eliminated from the sewage plant flow by by-passing them at great expense through a long pipeline into Lake Michigan. Digestion troubles recurred in 1943, when another plant began discharging its wastes into the system.

Riehl (9) reports similar effects in several Ohio communities, particularly at Fostoria, where a raw sewage con-

taining 8.8 p.p.m. copper and 56 p.p.m. zinc produced a raw sludge containing 691 p.p.m. copper and 1,934 p.p.m. zinc, which concentrated to 978 p.p.m. of copper and 8,508 p.p.m. of zinc in digesters. Digestion stopped completely.

Coburn (10) set the allowable limits of copper at 1 p.p.m. for primary treatment with sludge digestion, or for secondary treatment. For primary treatment without sludge digestion he set a limit of 3 p.p.m.

Both Coburn (10) and Laboon (11) set the upper limit of chromium for primary treatment at 5.0 p.p.m.

Other metal waste products have a deleterious effect on secondary processes but, because the problem at Waterbury concerned primary treatment, no extensive investigation of these effects was made.

From an analysis of the available information it was concluded that the effect of copper on digestion was well enough established so it was only necessary to determine whether sufficient copper or chromium was present in the Waterbury sewage to eliminate digestion as a method of sludge treatment.

Field Investigation

A brief but intensive investigation was initiated in Waterbury in March 1949. A temporary laboratory was established in a vacant schoolhouse centrally located with respect to the projected sampling stations on the sewer system. Although major units in the laboratory, such as the hood, were improvised, some equipment, including the furnace and oven, was purchased with the intention of using these items eventually in the laboratory of the sewage treatment plant. Distilled water was purchased from a local chemical supply house and, as is often the case, the distilled water contained significant concentrations of the metal under study—in this instance about 0.2 p.p.m. of copper.

Methods of Analyses

Chemical procedures were established after considerable preliminary investigation so as to minimize the manipulation and time required for each analysis. Samples for the determination of copper and chromium were "wet ashed" by digestion with concentrated sulfuric and nitric acid, essentially as described by Sandell (12). A 100-ml. sample, to which 4 ml. of concentrated sulfuric acid and 2 ml. of concentrated nitric acid were added, was heated to fuming in a 125-ml. Florence flask. This type of vessel was found desirable because the small amount of acid residue covers the bottom of the vessel completely, thus keeping all the salts in solution. The residue was always clear, but generally colored when large quantities of chromium or copper were present. The digested sample was made up to 50 ml. with distilled water and divided equally for determination of copper and chromium.

For copper, 25 ml. of the digested sample were neutralized with ammonium hydroxide to the methyl orange end point, checked with phenolphthalein to avoid making the sample too alkaline, and made up to 50 ml. The sample, or an aliquot portion made up to 50 ml., was dosed with 2 ml. of diethyldithiocarbamate solution (1 g. per 100 ml.) and compared in Nessler tubes with standards prepared in concentrations from 0 to 2 p.p.m. For very rapid work, it was possible to compare these directly, but for more precise determinations, the unknowns and standards were extracted with carbon tetrachloride and the extracts were compared. A sample found to have 7.9 p.p.m. copper by electroplating in a mill laboratory had shown a 7.5 p.p.m. copper concentration by the method described above.

For chromium, 25 ml. of digested sample was boiled for 10 min. with 2 ml. silver nitrate solution (1.4 g. per

liter) and 10 ml. ammonium persulfate (8 g. per 100 ml.) to oxidize the chromium. After making up to 50 ml., the sample, or an aliquot portion, was dosed with diphenyl carbazide solution and compared with standards.

Cyanide was determined by the phenolphthalein method described by Riehl (9); other determinations were made in accordance with "Standard Methods" (13).

Procedure

Twenty sampling stations were selected on the sewer system, with five chosen for round-the-clock sampling. These five included three on the Main Carrier along the Naugatuck River, one of which was at the outfall near the sewage treatment plant site, and one on each of two principal feeder sewers.

In order to pick up peak concentrations of metals resulting from dumping of vats in industrial plants, grab samples were collected every two hours and determinations for temperature, pH, alkalinity or acidity, and cyanide were made immediately. The four samples collected at each station over an 8-hr. shift were then composited in proportion to the measured sewage discharge at the outfall, and these composites were analyzed for copper, total chromium, fixed and volatile suspended solids, and fixed and volatile total solids. Special tests were run on individual grab samples showing unusually low or high pH, or color.

The sampling was carried on almost continuously for one week with several 8-hr. shifts omitted. During the period of this investigation, in March 1949, the mills in Waterbury were on one-shift operation, with little activity on Friday and virtually no activity on Saturday and Sunday. It was possible, therefore, to omit sampling Saturday night and Sunday morning, and an occasional graveyard shift, without losing significant data.

Results

The characteristics of the sewage in the Main Carrier at the treatment plant site are shown graphically in Figure 3. The influence of the industrial wastes on the sewage is apparent. During the 9 A.M. to 5 P.M. shift on each midweek day, except Friday, when industrial operations were curtailed, the pH at the plant site dropped below 4.5, and the copper concentration exceeded 7 p.p.m. The average copper concentration over the week sampling period was 2.6 p.p.m.

The effect of mill operations on the pH and on the copper concentration in the sewage in the Main Carrier at the outfall is summarized in Table I. The table includes data collected by one of the authors after completion of the March 1949 survey, and illustrates clearly the effect of restricted mill operations during vacation periods.

Samples of alkaline sewage containing copper found during work-day periods when the large mills were not operating is attributed principally to the discharge of alkaline wastes from the numerous small plating plants using alkaline processes. Sewage during night hours, on the other hand, when all shops are shut down, is little different from plain domestic sewage.

Analyses of samples collected at other sampling points on the sewer system showed similar effects of industrial contributions, and even higher concentrations of metals were found. For example, an 8-hr. composite sample on the Main Carrier within the city contained 42 p.p.m. of copper and 30 p.p.m. of chromium. Table II shows analyses of grab samples of sewage from the Main Carrier and sewer laterals. The most noteworthy are the samples from the Main Carrier containing 110 to 120 p.p.m. of copper and 70 to 80 p.p.m. of chromium and the seven samples collected from a

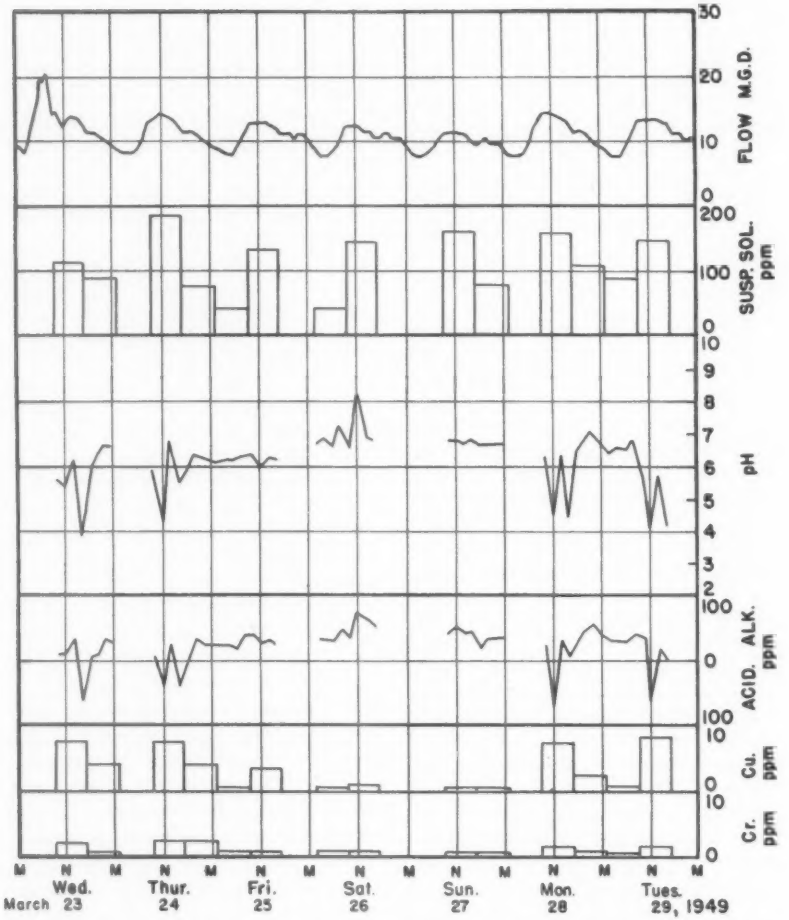

FIGURE 3.—Characteristics of Sewage in Main Carrier at proposed treatment plant site.

lateral containing an average of 1,060 p.p.m. of copper.

The results of the tests indicate that the city's industrial waste ordinance was ineffective in reducing copper and chromium to tolerable limits. This ineffectiveness is partially, at least, brought about by the fact that (a) it has proved impractical for the smaller plants to separate or treat their wastes to any great extent and (b) some of the larger plants use river water already containing substantial quantities of metal wastes for flushing and sanitary waste water supply.

Inasmuch as copper averaged about 2.6 p.p.m. over the intensive sampling period and was well above allowable limits, the impracticability of biological methods of sludge treatment was obvious. However, even with a non-biologic method of sludge treatment, the need for better control of acid and other wastes, which might damage

TABLE I.—Effect of Mill Operation on pH and Concentrations of Copper and Chromium in Sewage at Waterbury Treatment Plant Site

Mill Operation	Date	Days	Time	No. of Tests for Metals	pH[1]		Copper (p.p.m.)		Chromium (p.p.m.)	
					Range	Median	Range	Mean	Range	Mean
Mills working (no third shifts)	3/23–29/49	Weekdays	9 A.M.–5 P.M.	5[2]	3.8 to 6.8	5.8	7.5 to 8.5	7.8	0.10 to 2.0	1.3
			5 P.M.–1 A.M.	3[2]	5.8 to 7.1	6.4	2.5 to 4.0	3.5	0.16 to 2.0	0.89
			1 A.M.–9 A.M.	2[2]	6.1 to 6.8	6.4	0.05 to 0.5	0.3	0.02 to 0.08	0.05
Mills not working		Sat. and Sun.	All Day	4[2]	6.5 to 8.2	6.8	0.1 to 0.5	0.2	0.00 to 0.04	0.02
Most mills closed for vacations	7/6–8/49	Weekdays	9 A.M.–5 P.M.	3[2]	6.9 to 9.2	7.1	0.3 to 0.6	0.5	0.01 to 0.06	0.03
Mills working	7/18–11/3/49	Weekdays	9 A.M.–5 P.M.	32	5.3 to 8.3	6.5	1.0 to 12.5	5.1	0.00 to 2.5	0.55
Some mills closed for vacations	7/13/50	Weekday	9 A.M.–7 P.M.	7	6.7 to 8.9	7.1	1.1 to 3.0	1.9	0.04 to 0.43	0.13
Mills working	7/31–8/1/50	Weekdays	9 A.M.–5 P.M.	5	4.9 to 6.5	6.3	2.6 to 5.0	3.5	0.12 to 0.40	0.21
			5 P.M.–1 A.M.	4	6.2 to 6.6	6.5	0.8 to 5.4	2.9	0.05 to 0.25	0.15
			1 A.M.–9 A.M.	3	6.7 to 7.2	6.8	0.4 to 2.6	1.3	0.03 to 0.06	0.05

[1] pH run on individual samples.
[2] Composites of all samples taken during each 8-hr. period.

TABLE II.—Some High Concentrations of Copper and Chromium in Grab Samples

Sampling Point	Dates	Time	No. of Samples	pH	Copper (p.p.m.)	Chromium (p.p.m.)
Main Carrier, No. 2	3/28/49	4 P.M.	1	3.2	120	70
Main Carrier, No. 3	3/28/49	4 P.M.	1	3.2	110	80
M.H. near Plant No. 23	3/28–8/17/49	9 A.M.–5 P.M.	7	2.7 to 3.3	16 to 70	0.6 to 15
M.H. near Plant No. 57	7/27–11/1/49	9 A.M.–5 P.M.	11	1.9 to 2.9	5 to 45	0.0 to 0.6
M.H. near Plant No. 13	3/9/50	9 A.M.–5 P.M.	7	1.9 to 6.0	1,060[1]	0.0
M.H. near Plant No. 115	8/30/49	3 P.M.	1	>10.2	100	0.0

[1] Composite of seven samples.

sewers and treatment plant structure or create hazardous operating conditions, is apparent. The city plans to continue its efforts to exclude such wastes from the system.

Summary and Conclusions

An intensive sampling program of Waterbury, Conn., sewage indicated quantities of copper and chromium in excess of amounts that could be tolerated by a plant with sludge digestion as a part of the treatment process.

The basic purpose of the survey was to determine if sludge could be treated by digestion or should be handled by a non-biologic process. The results of the tests conclusively indicate that sludge digestion would be unsuccessful or, at the best, would create serious operating difficulties. Therefore, the review report recommended the use of a non-biologic treatment for the sewage sludge.

Acknowledgments

The cooperation and assistance of those who helped in the investigation is gratefully acknowledged. Special mention should be made of the city engineer and his staff; also of John R. Freeman, Jr., of the American Brass Company, chairman of the Water Resources Advisory Group, Naugatuck Valley Industrial Council. Chemists of the State Health Department, Wesleyan University, and the American Brass Company were particularly helpful in establishing chemical procedures.

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HATFIELD CONSULTANT TO A.E.S. RESEARCH

W. D. Hatfield, chairman of the Standard Methods Committee, Federation of Sewage and Industrial Wastes Associations, has been appointed as consultant to Research Project Committee No. 2 of the American Electroplaters' Society.

The project, headed by E. J. Serfass at Lehigh University, is engaged in development work on analytical procedures for determination of hazardous ions in electroplating wastes.

RENDERING PLANT WASTE TREATMENT STUDIES *

By Marvin L. Granstrom

Assistant Professor of Sanitary Engineering, School of Public Health, University of North Carolina, Chapel Hill, N. C.

The purpose of a rendering plant is to convert inedible poultry, fish, and animal offal and waste products into animal feed and grease. This is accomplished by cooking the inedibles at a high temperature for a period of several hours. The cooked material is pressed to remove the grease and the pressings are ground for feed. The cooking process gives off odorous vapors; the control of this odor is accomplished by condensing the vapors in large quantities of water and by burning the non-condensable vapors. About 150 g.p.m. of water are required for a 5-ton cooker. This water is only slightly contaminated and generally requires no treatment.

The source of strong liquid wastes is the washing of trucks, barrels, and floors. It is of these wastes that this study has been made. Particularly during the warm months, the waste is in a state of partial decomposition due to the time lag between the slaughter or dying of the animal and the rendering process. This waste is strong, black, smelly, and septic. Most of the organic matter is in a dissolved state. The degree of treatment required is dependent on the allowable pollution load of the receiving watercourse.

Waste Treatment Plant

The rendering plants, when separate from slaughterhouses, are generally small and removed from a public sewer system. Little or no scientific control of plant operation is required. A treatment plant, therefore, should meet the following considerations:

1. Low capital investment.
2. Minimum mechanical equipment.
3. Economical and simple to operate.
4. Apparent results to encourage operation.

Of the various waste treatment processes, chemical coagulation was selected to best fit the above considerations. A rendering plant near Chapel Hill was selected for study. This plant had constructed a sewer system, a grease trap, and a combination floculator and clarifier having a hopper bottom. A sludge pump was installed, but no provision had been made for sludge disposal. The clarifier was drained when full, which was about once a day. The quantity of waste water is about 1,000 gal. per ton of animal food produced. The washing cycle allowed the use of the batch treatment technique.

It was decided to use filter alum and chlorine as the chemicals. Each performs two functions: the alum reacts with the bicarbonate alkalinity to form the floc and the CO_2 produced reduces the pH; the chlorine oxidizes the reduced material and coagulates the protein. The protein coagulation is most effective at a pH from 4.0 to 4.5. No satisfactory method was known to feed large quantities of chlorine gas in the short period of time desired for operation, so it was decided to use calcium hypochlorite as the source of chlorine. The solution feed devices available were too slow, so the

* Presented at 1950 Annual Meeting, North Carolina Sewage and Industrial Wastes Assn.; Durham, N. C.; Nov. 13–15, 1950.

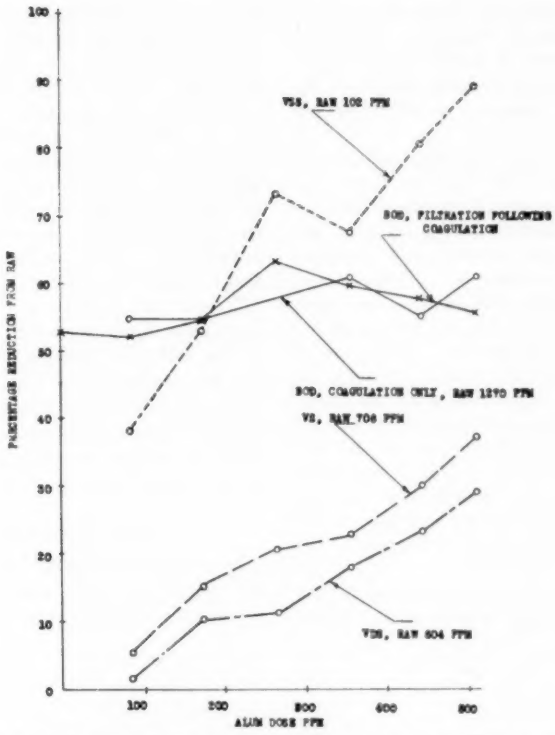

FIGURE 1.—Effect of varying alum dose; chlorine dose constant at 177 p.p.m.

writer designed and constructed one which consisted of two 55-gal. drums, from which the solution was pumped to a pipe grid system. The pipe grid provided good distribution and, from the jetting action, some mixing; 100 gal. of solution could be fed in 7 min.

Laboratory Investigations

All B.O.D. values herein mentioned refer to 5-day, 20° C. values.

Prior to plant operation a series of laboratory investigations were made to attempt to determine: the order of magnitude of dosages required, the effect of sand filtration, the effect of pH control, and the effect of pre-aeration. A preliminary visual and olfactory study indicated that the higher the chlorine dose, the lighter the color; the higher the alum dose (up to the limit of the bicarbonate alkalinity), the better the clarification; and that the pH should not be reduced below about 4.0.

Figure 1 indicates the effect of varying the alum dose with a constant chlorine dose of 177 p.p.m. Improved clarification is noted by the reduction of volatile solids (V.S.), volatile suspended solids (V.S.S.), and volatile dissolved solids (V.D.S.). However, since about 85 per cent of the V.S. are V.D.S. the net removal of V.S. is not very great. The B.O.D. reduction is not appreciably affected by the increase in alum dose. Filtration of a part of the coagulated portions through

12 in. of sand had little effect on the B.O.D. removal. Filtration of the raw sample showed a B.O.D. reduction of the same order of magnitude as the coagulation process; namely, 53 per cent.

Figure 2 shows the effect of varying the chlorine dose with the alum dose held constant at 177 p.p.m. The percentage reduction of V.S., V.S.S., and V.D.S. is not significantly changed with the increase of chlorine dose. For this particular sample the range of chlorine dose was too low to give a good B.O.D. reduction. Filtration of part of the coagulated portions resulted in approximately the same B.O.D. removal, irrespective of the chlorine dose. Filtration of the raw sample resulted in a B.O.D. reduction of 24 per cent. Aeration of the raw sample resulted in an increase in pH and only a 7 per cent reduction of the B.O.D.

Figure 3 shows the results of B.O.D. reduction using various combinations of alum and chlorine doses. The set of curves showing the effect of varying the alum dose with a constant chlorine dose substantiates the findings shown in Figure 1; namely, that above 150 to 200 p.p.m. no appreciable increase in B.O.D. removal is noted. The set of curves showing the effect of increasing the chlorine dose with the alum dose held constant is rather remarkable. Little change is noted in B.O.D. reduction between a dose of 177 and 264 p.p.m., but above 264 p.p.m. the jump is abrupt. Reduction of the pH to 4.5 has little effect on B.O.D. reduction at the upper and lower chlorine doses, but at the intermediate dose the effect is quite evident, becoming increasingly effective as the alum dosage increases.

Plant Operation

Various combinations from 120 to 700 p.p.m. of alum and 120 to 240 p.p.m. of chlorine were used during

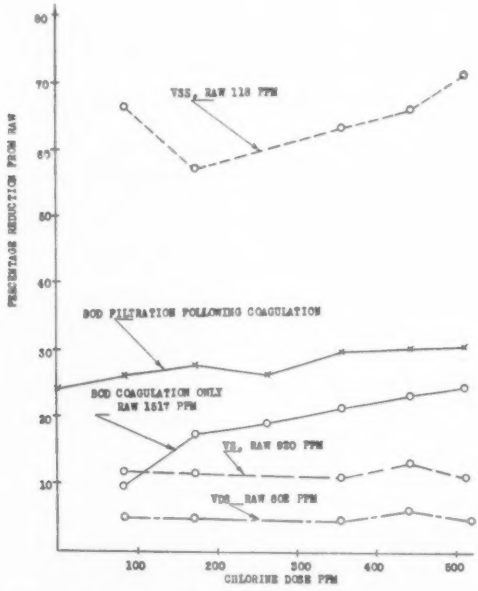

FIGURE 2.—Effect of varying chlorine dose; alum dose constant at 177 p.p.m.

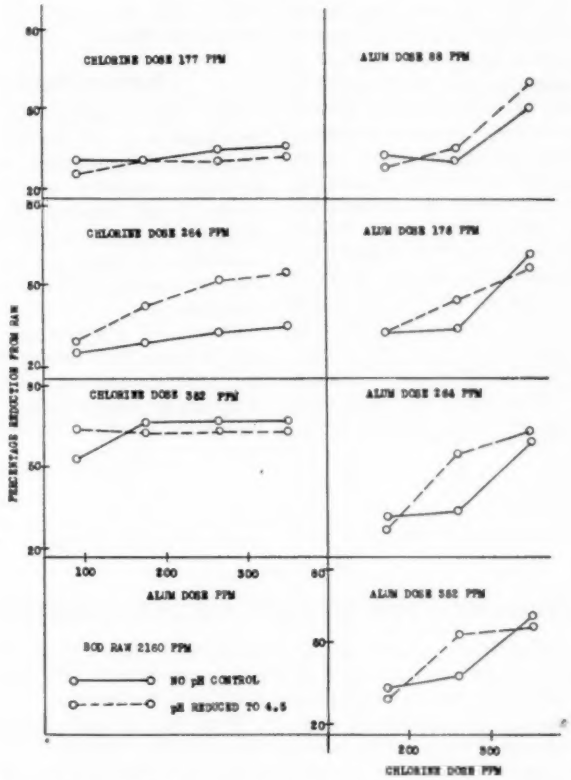

FIGURE 3.—Effect of various combinations of alum and chlorine.

the operation study of the plant. The increase of alum dose above 120 p.p.m. did not significantly increase the B.O.D. removal, but clarification was improved. With 120 p.p.m. chlorine the B.O.D. was reduced an average of 60 per cent with a range from 55 to 73 per cent. The 73 per cent reduction occurred on a sample having a B.O.D. of 3,750 p.p.m.; the 55 per cent reduction occurred on a sample having a B.O.D. of 1,500 p.p.m. The 240 p.p.m. chlorine dose resulted in a B.O.D. reduction between 55 and 76 per cent, with an average of 68 per cent. Again, the greater reduction occurred with the stronger sample. Filtration of a portion of the settled wastes has an insignificant effect on B.O.D. solids, and light transmission. Reduction of pH from 6.0 to 4.9 by H_2SO_4 following the alum and chlorine improved the B.O.D. removal by 60 per cent. The B.O.D. reductions were better than indicated by the laboratory studies. Solids reduction followed the pattern shown by the laboratory experiments. Improved clarification and reduction of color improved light transmissibility four- to six-fold.

Conclusions

Chlorine and alum, if used in sufficient quantities, will appreciably re-

duce the B.O.D. and color and result in improved clarification. The cost of the chemicals is high. The B.O.D. of the raw waste is from about 1,500 to 3,800 p.p.m.; the B.O.D. of the treated waste, using the dosages mentioned above is from 400 to 600 p.p.m. Most of the organic matter is in solution, due to the state of partial decomposition of the waste. The rate of B.O.D. removal decreases as the dosages increase. To reduce the B.O.D. to levels much below 400 to 600 p.p.m. would necessitate much higher dosages. The industry might tend to be lax in adding the chemicals. The author intends to install a pilot plant size recirculating trickling filter and secondary settling tank to study the biological treatment effects.

Acknowledgments

The author wishes to express his gratitude to J. M. Jarrett and E. C. Hubbard, state sanitary engineer and principal sanitary engineer, respectively, North Carolina State Board of Health, for their suggestions and encouragement, and to J. B. Berlin for his assistance in the laboratory analysis.

The study reported herein was begun in July, 1950, under the direction and with the support of the Division of Sanitary Engineering, North Carolina State Board of Health.

VERMONT RATIFIES NEW ENGLAND COMPACT

On June 29, 1951, Governor Lee E. Emerson of Vermont executed the New England Interstate Water Pollution Control Compact on behalf of that state and appointed the Commissioners as provided under the Vermont legislation. The Commissioners representing Vermont are: Dr. Robert B. Aiken, Commissioner, State Health Dept., Montpelier; Philip Shutler, Commissioner, State Water Conservation Board, Montpelier; George W. Davis, Director, State Fish and Game Service, Montpelier; Frederick W. Shepardson, Proprietor, Maltex Company, Burlington; and George H. Plumb, Village President, Bennington.

With the formal ratification of the Compact by Vermont, the signatory states now include five of the seven eligible states; namely, Massachusetts, Connecticut, Rhode Island, New York, and Vermont. Now pending before the present legislative session in New Hampshire is legislation authorizing that state to ratify the Compact, with every indication that enactment will soon result.

TREATMENT OF PHARMACEUTICAL WASTES *

By James M. Brown

Sanitary Engineer, Lederle Laboratories Division, American Cyanamid Co., Pearl River, N. Y.

This paper deals with the solution of the industrial waste problems at the Lederle Laboratories Division, American Cyanamid Company, a biological and pharmaceutical plant located at Pearl River, N. Y. It is thought that these problems are not unique, but may be involved in the operation of similar plants.

Growth of Problem

The growth of biological and pharmaceutical plants was greatly accelerated during World War II by the enormous demands of the Armed Forces for the life-saving products these plants manufacture. The biological products produced through animals (such as smallpox vaccine, gas gangrene antitoxin, diphtheria antitoxin, etc.) were responsible for large quantities of animal waste. The manufacture of liver products involved the processing of tons of hog or beef liver pulp, as well as large quantities of wash water. Manufacture of new products, particularly antibiotics, which were developed during World War II, and which later proved their peacetime usefulness, greatly increased the waste treatment problem resulting from this industry. The waste treatment problem, which in the past had been relatively unimportant, suddenly mushroomed into a one of major importance and of a different type. This required expansion of present plants or modification to provide a different type of treatment. The treatment of wastes from these antibiotics has created a new problem to these plants—the treatment and disposal of wastes containing many tons of organic material in solution for each ounce of finished product.

The Lederle plant was not an exception. During the war it was called upon to produce blood plasma, vaccines, and penicillin for the armed forces. The plant increased in size from 700 employees in 1940 to 2,800 people at the end of the last war. Currently it employs over 4,000 workers.

The waste problem is further complicated by the location of this plant on the watershed of a potable water supply. The plant effluent is discharged to the town plant, the effluent of which is discharged into a small stream forming a part of the raw water of a public water supply. During the summer months the dilution ratio, at times, amounts to less than 5 to 1.

Types of Wastes

Liquid wastes from pharmaceutical plants producing antibiotics and biologicals can be classed as follows:

1. Strong fermentation beers. These are small in volume, but have a high B.O.D. (4,000 to 8,000 p.p.m.), due to nutrient dissolved solids in solution. Aureomycin, like penicillin, is produced by fermentation in a medium containing sugars, corn steep liquor, and nutrient salts, which are added because they aid the growth of the organism.

2. Inorganic solids, such as diatomaceous earth (filter cel), which is used in the filtering process. A layer of filter cel is built on the wire mat of a vacuum filter as a filter aid in removing the mycelium. When the layer is re-

* Presented at 1951 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York City, N. Y.; January 19–20, 1951.

TABLE I.—Pilot Filter Performance Data

Date	Biochemical Oxygen Demand				Recirculation Rate
	Raw (p.p.m.)	Final (p.p.m.)	Reduction (%)	Loading (lb./acre-ft.)	
8/25	2,150	680	68.5	12,000	8:1
8/27	2,500	725	71.0	12,000	8:1
9/1	2,600	1,400	46.4	14,000	4.3:1
9/3	2,500	1,900	23.0	12,000	1.5:1
9/8	2,700	1,800	33.3	14,000	1.3:1
9/9	2,150	940	56.4	11,400	4:1
9/10	2,200	1,000	54.5	10,800	4:1
9/15	1,520	680	50.5	10,800	3:1
9/22	2,000	1,000	50.0	12,000	3:1
10/20	1,750	900	48.6	15,000	4:1
10/22	600	240	60.0	18,000	4:1
10/27	750	300	60.0	18,000	4:1
10/29	575	270	53.5	18,750	4:1
10/31	700	415	40.7	14,000	2:1
11/3	400	180	55.0	8,000	4:1
11/10	1,000	450	55.0	8,500	3:1
11/12	500	230	64.0	7,200	4:1
11/15	480	220	54.2	7,200	4:1
11/18	680	280	58.0	7,200	4:1
11/20	580	240	58.7	7,500	4:1

moved, a portion of the filter coat is discharged to the sewer in the form of a waste slurry. The waste has little B.O.D. However, it provides a solid load, which is discussed later herein.

3. Washings of floors and equipment, which range in B.O.D. from 600 to 2,500 p.p.m. and contribute a large percentage of the hydraulic load.

4. Chemical waste. This may include weak solutions of solvents, either too weak to recover, or the effluent from stills where concentrated solutions of solvents are recovered for re-use. These may contain solvents in quantities as small as 0.1 per cent. These solutions will exert a substantial B.O.D. when diluted with other wastes. It has been found that 1 lb. of acetone exerts very nearly 1 lb. of B.O.D. when dilution is afforded so that the toxic limits are not met. The results of work by Heukelekian and others are most interesting in evaluating the amount of B.O.D. produced by solvents. Acids or alkalies inadvertently spilled to the sewer may also be included.

5. Barometric condenser water from evaporation or drying processes. These wastes result from entrainment of solids or from volatile gases being mixed with the condenser water. They may contain B.O.D. values from 60 to 120 p.p.m. and often may not be discharged to the sewer because the excessive volume of water involved would hydraulically overload the treatment plant. As a barometric condenser may pull as much as 25 per cent of the total B.O.D. from the evaporating liquor and discharge it to the sewers, the treatment of this waste must be considered in the treatment program.

Treatment of Wastes

Solid wastes from the Laboratories, including infected manures, glassware, waste filter cakes, garbage from the cafeteria, and miscellaneous trash from the Laboratories, are destroyed in a duo-hearth incinerator. Sewage sludge cake or filter cake having a moisture content of 60 to 70 per cent is dried on the first hearth before falling onto the combustion hearth. The ash is used to fill in low-lying areas.

During the war and in the early

postwar years, when the company produced penicillin, the spent penicillin broth was evaporated to a slurry containing 10 to 15 per cent solids. It was then spray dried to produce a fortified supplement for poultry feeds. The filtrate from the fermentation of aureomycin, which was developed by Lederle shortly after the end of the war, proved impractical to spray dry. This was due, in part, to the caramelizing effect of the sugars in the filtrate. Other means of treating the filtrate or the fermentation beer were investigated. High-rate filtration was considered and a 6-ft. pilot plant was built with a 3-ft. depth of 2½-in. trap rock. The wastes applied to the filter were a combination of the industrial waste from the treatment plant and the strong fermentation filtrate wastes, which had a B.O.D. of 5,000 to 6,000 p.p.m. The combination had an incoming B.O.D. of around 2,000 p.p.m. The B.O.D. reductions by the pilot plant are shown in Table I. Loadings in excess of 10,000 lb. B.O.D. per acre-ft. per day were applied without any apparent breakdown of the filter, although these high loadings were never maintained for long periods of time. This experimental plant was used to obtain design data for the full-sized plant.

The first 100-ft. filter (Figure 1) was completed in July, 1949. It provided a 6-ft. depth of trap rock sized from 2½ to 3½ in. and laid without an outside supporting wall, allowing the stone to assume its own natural slope. The purpose of this type construction was to allow more air to circulate through the side of the bed. Its value could never really be evaluated, as no comparison can be made with a similar filter having conventional sides. In July, 1950, a second filter was built, similar to the first. Each was preceded by a 40-ft. circular clarifier with a 9-ft. side water depth, providing 1.5-hr.

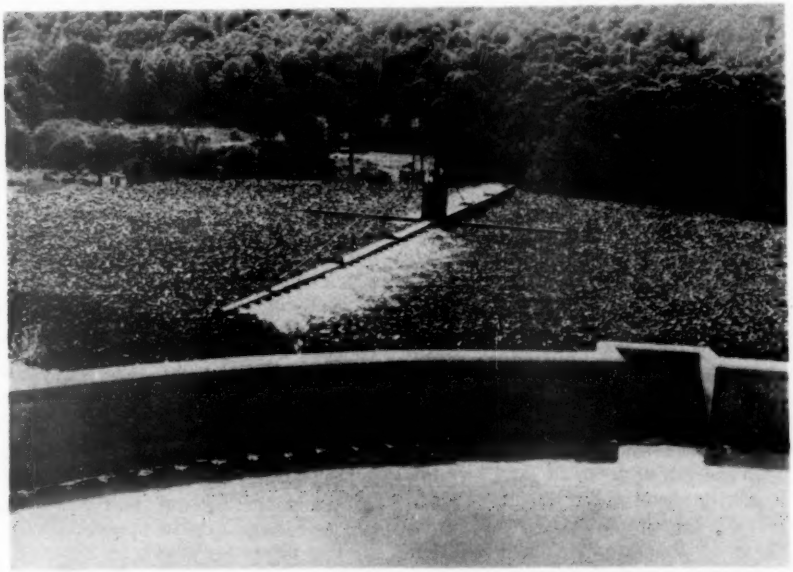

FIGURE 1.—Construction without side walls allows greater air circulation in 100-ft. diameter high-rate filter handling pharmaceutical wastes.

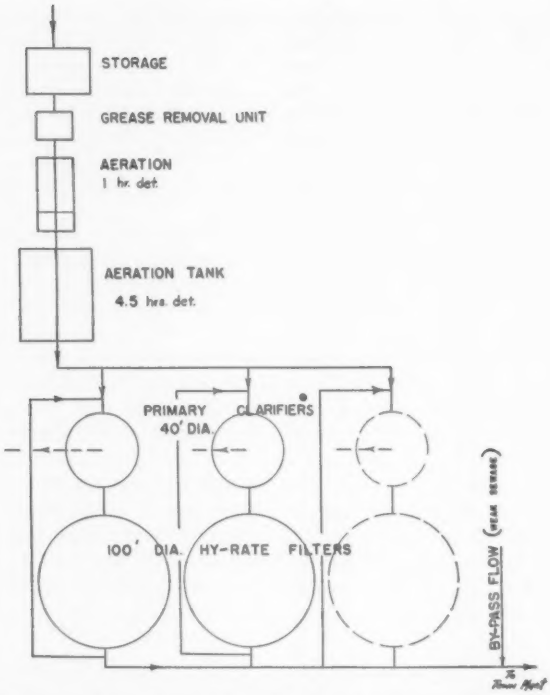

FIGURE 2.—Flow sheet of Lederle industrial waste treatment plant.

detention at a 3 to 1 recirculation rate. A third filter and clarifier are under construction, as well as a secondary clarifier. The ultimate arrangement of these units is shown in Figure 2.

The total flow discharged from Lederle to the town treatment plant amounts to 800,000 g.p.d. The industrial waste plant presently handles 400,000 g.p.d. of the strong waste, high in B.O.D., while the weaker waste is discharged directly to the town plant without treatment. The flow from Lederle represents 60 per cent of the flow at the town plant.

In the fall of 1950, an aeration tank was built ahead of the clarifiers to provide 4.5-hr. aeration at the rate of 1.5 cu. ft. of air per gallon. The aeration tank was equipped with four swing diffusers having 19 saran-wrapped diffusers in each swing. The wastes tend to clog these diffusers. However, as only four swings are involved, they can be raised weekly and washed off with a hose. In this operation one set is taken off and soaked in a detergent until the following week, when the set which has been soaking is exchanged in rotation for another set. Some of the clogging seems to occur on the surface. This can be washed off by the action of a jet of water and the swings returned to service.

Treatment Results

The results of approximately 16 months of operation of filter No. 1, as well as four months of operation with the two filters are shown in Figure 3. A great deal of thought was given to the tests which would give the best

evaluation of the work done by the filters. Oxygen consumed by various reagents, including potassium dichromate, was given consideration. However, it appears that the standard B.O.D. test is as valid as any that could be found. The oxygen consumed test is not a true chemical oxygen demand, as potassium dichromate is only capable of breaking down a portion of the organic matter. A more correct title for this test would be oxygen consumed by potassium dichromate. It is recommended that the use of the term C.O.D. be discouraged, as it implies a wrong conception of the work accomplished by the test. There is a great need in the industrial waste field for a test indicating the amount of organic material in wastes where the results can be obtained in less than the usual five days. A great deal of work in checking wastes at the source is accomplished in checking the strength of these wastes by oxygen consumed by potassium dichromate where the production section can be kept posted on the condition of the wastes leaving the section.

The Lederle work on oxygen consumed by potassium dichromate follows the work by Johnson, of Wisconsin. Some results are shown in Figures 4 and 5. It shows that the oxygen consumed values bear a relationship with B.O.D. More work is needed to determine if the constants vary because of the character of the waste or because of laboratory errors due to the relatively small amount of samples taken.

Figure 3 shows the B.O.D. loading and results of operation of filter No. 1 and filter No. 2. A seasonal drop was experienced during the winter of 1949–

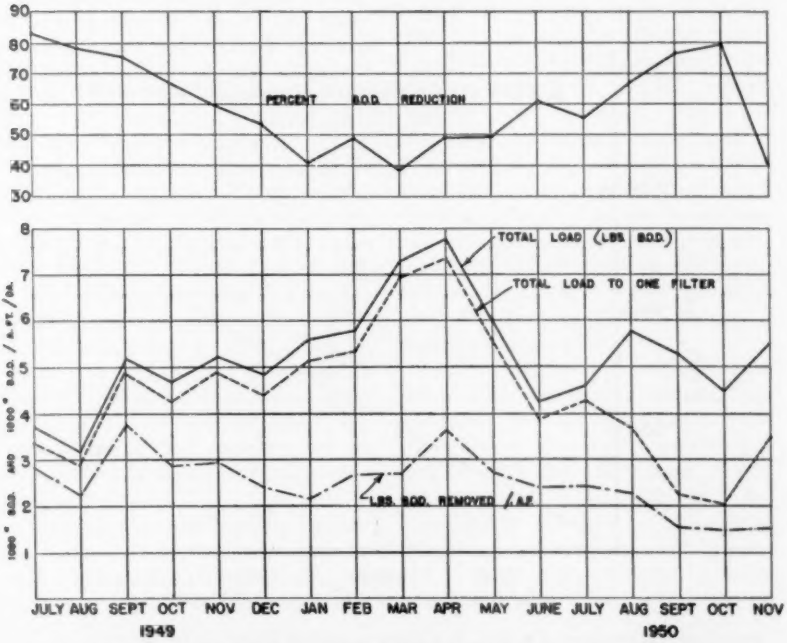
PERCENT B.O.D. REDUCTION
TOTAL LOAD (LBS. B.O.D.)
TOTAL LOAD TO ONE FILTER
LBS. B.O.D. REMOVED / A.F.
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV
1949
1950

FIGURE 3.—Operating results of high-rate trickling filters treating pharmaceutical wastes.

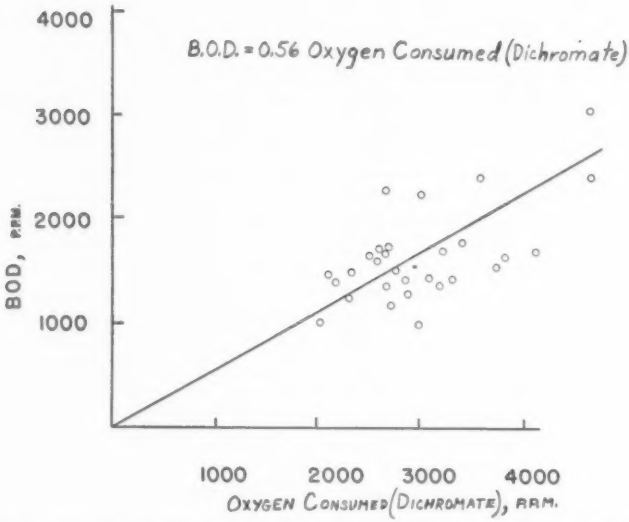

FIGURE 4.—Relation of B.O.D. to oxygen consumed (dichromate) for raw wastes.

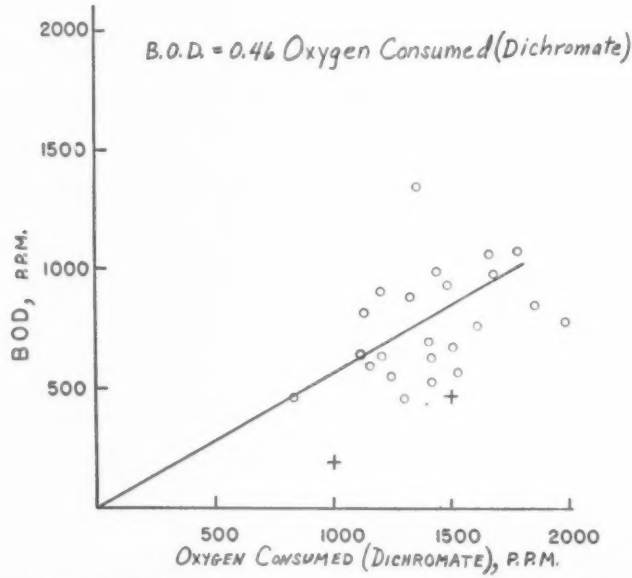

FIGURE 5.—Relation of B.O.D. to oxygen consumed (dichromate) for filter No. 2.

50 and again during the winter of 1950–51. This reduction in B.O.D. is far more severe than the results reported for filters handling domestic sewage, although many variables have entered into the picture which may or may not have had a part in a reduction or slowdown in the bacteriological life on the filter.

The reduction through the filter has fallen off during the winter months; however, the reduction in the aeration tank increases during these cooler months. A 500-c.f.m. blower furnishes 1.5 cu. ft. of air per gallon of waste. However, even at these high rates dissolved oxygen cannot be maintained in the aeration tank except during cold weather. When the temperature of the wastes drops below 65° F., dissolved oxygen values as high as 4.0 p.p.m. can be maintained. The discharge of hot process wastes into the sewer results in a normal summer temperature in the aeration tank of 85° to 95° F., while peak temperatures of 100° F. are not uncommon. The B.O.D. removal through the aeration tank during December, 1950, amounted to 30 per cent, with the influent having a B.O.D. of 2,500 p.p.m. and the effluent having a B.O.D. of 1,750 p.p.m. The suspended solids of the stored sewage are 1,000 to 1,200 p.p.m. Sixty per cent of these are non-volatile. The high ash is due, in large part, to the filter cell in the wastes. During aeration a floc is built up, the solids rise to about 1,500 to 2,000 p.p.m., and the non-volatile solids drop to 50 per cent of the total, showing a build-up in the aeration tank of an organic floc, which when settled accomplishes a further B.O.D. reduction by the clarifier.

Irregular pH values during October and November, 1950, necessitated installation of a pH recorder. Low pH values are now controlled by the addition of sodium hydroxide solution to the wastes to maintain a pH of 6.7 in the storage tank, which is an important part of each industrial waste plant. The low pH values resulted from inadvertent spills of acid and from processing areas producing waste material of low pH.

Reduction of Wastes

Much can be done in the treatment of wastes at the source, and the importance of educating the manufacturing section on the importance to the plant of industrial waste treatment cannot be overemphasized. Sewers should be used only to transport those industrial wastes which may be treated with existing equipment. The remainder should be kept out of the sewers by collecting and disposing of them separately.

Many times processes can be changed without any effect on production in an attempt to keep detrimental waste from the sewer. It is the full-time duty of a chemical engineer assigned to the plant's Industrial Waste Section to survey the manufacturing processes to determine methods of keeping organic material out of the sewer. Due to the changes in the manufacturing processes, frequently a process which has no industrial waste problem and which discharges directly to the town plant may develop into one having a sizeable amount of industrial waste, which then requires repiping to the industrial sewer line discharging to the industrial waste treatment plant.

In the spring of 1950, at the time the second filter was built, a vacuum filter was added to dewater the sludge from the clarifiers. Two 40-ft. circular clarifiers having a side water depth of 9 ft. are used to settle the waste before application to the filters. The sludge from the clarifiers has a solids content of 8 to 13 per cent, with an ash content of 60 to 70 per cent. The high ash content, as well as the high solids content of the sludge, is due to the large amounts of filter cel which is scraped

TABLE II.—Operating Results (p.p.m.)

Test	1949					1950									
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
(*a*) Storage (Raw)																
B.O.D.	1,280	1,674	2,240	2,020	2,270	2,673	2,397	3,140	2,595	1,864	1,455	1,675	2,130	2,529	2,320	2,530
Sus. sol.	..	..	..	1,590	969	1,431	1,220	1,000	1,344	1,192	1,240	1,124	1,340	2,050	1,543	1,212
Org. nit.	49	..	..	16	16	41	32	27	24	31	35	31	37	32	31	27
Tot. nit.	47	..	..	47	67	57	101	66	79	75	80	79	142	80	95	98
(*b*) Aeration Effluent																
B.O.D.	1,245	1,497	1,923	1,650	2,001	2,243	2,025	2,770	2,640	1,585	1,200	1,475	1,700	1,800	1,581	1,910
Sus. sol.	—	—	—	—	—	—	—	—	—	—	—	—	—	2,480	1,460	1,465
Org. nit.	—	—	—	—	—	—	—	—	—	—	—	—	—	44	44	21
Tot. nit.	—	—	—	—	—	—	—	—	—	—	—	—	—	97	100	69
(*c*) Filter No. 1																
B.O.D.	266	453	535	790	920	1,330	1,026	1,700	1,330	790	470	665	910	668	796	1,100
Sus. sol.	—	—	—	191	169	225	260	260	278	257	167	176	228	293	256	278
Org. nit.	16	—	—	10	7	19	22	16	17	16	18	15	23	20	17	29
Tot. nit.	19	—	—	28	39	25	74	63	56	49	52	49	65	60	70	105
(*d*) Filter No. 2																
B.O.D.	—	—	—	—	—	—	—	—	—	—	—	—	536	190	306	932
Sus. sol.	—	—	—	—	—	—	—	—	—	—	—	—	384	114	187	156
Org. nit.	—	—	—	—	—	—	—	—	—	—	—	—	41	8	14	21
Tot. nit.	—	—	—	—	—	—	—	—	—	—	—	—	88	49	67	80

off the filter. Fortunately, the diatomaceous earth is an excellent sludge conditioner. No chemical conditioning except lime is needed to produce a filterable sludge. However, the diatomaceous earth plays havoc with pumps, produces excessive wear of the copper backing cloth on the vacuum filter, and produces excessive wearing of the chain drive clarifier mechanism at the town plant. An attempt is being made to minimize the wear of the equipment by using slower speed pumps, hardened metal impellers and casings, and stainless steel backing cloth.

Acknowledgments

Grateful acknowledgment is made to F. W. Mohlman, consultant; to L. L. Hedgepeth, Calco Division, American Cyanamid Co.; and M. T. Hill, district engineer, New York State Department of Health, for the part they played in the treatment program described, as well as the help they rendered in reviewing this paper.

SUGAR CANE PROCESS WASTES

By Ralph Stone

Sanitary Engineer, Los Angeles, Calif.

Sugar Cane Milling Processes

Sugar cane requires 18 months of growth before harvesting. When the cane stalks have a satisfactory sugar content, they are cut down and transported within a few hours to a sugar cane mill. There the stalks are squeezed in rotary extractors to release the sap containing the sucrose ($C_{12}H_{22}O_{11}$). Refined sucrose is our common table sugar. The cellulose residue (Figure 1) is dried out by air storage in a shed, and then burned to provide the heat energy for steam boilers and auxiliary power required in sugar manufacturing.

The squeezed sap is purified by skimming off the floating matter, called "cachaza"; evaporation of the excess water; and separation of the blackstrap molasses. Sulfur is added to provide a whiter final sugar product and small quantities of lime are employed for pH control. The surface skimming "cachaza" can be placed through a pressure or vacuum type filter to reclaim additional sugar sap. The fibrous filter residue is returned to the fields as fertilizer. Similiarly, the blackstrap molasses can be converted into alcohol and numerous other by-products or may be fed directly to cattle. Even the ash from the burned cellulose residue employed as fuel is valuable for agricultural fertilizer. Boiler water and waste wash water from the sugar cane mill are needed for irrigation of the cane fields.

It can be seen from this description of the sugar cane processing that all the waste products resulting from the production of sugar cane can and should be re-employed as a source of fuel, fertilizer, by-products, or irrigation water. Hence, the intelligently designed and operated cane mills should not have waste pollution problems and should provide the highest operating efficiency and monetary profits.

Cauca Valley Pollution Survey

A stream pollution survey of the Cauca Valley, in Colombia, South America, during July and August,

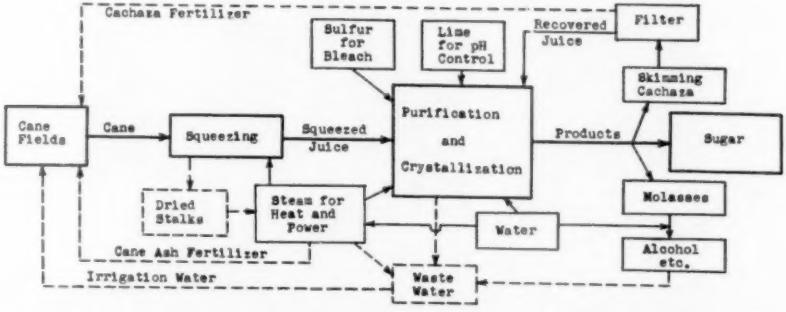

FIGURE 1.—Flow diagram of sugar mill operations, showing utilization and conservation of sugar, by-products, and waste water to minimize pollution of surface waters.

1950, demonstrated that the five-fold increase in cane production during the preceding decade has resulted in pollutional problems. In general, pollutional complaints had been based on taste, odor, and dead fish; no attention was paid to the presence of pathogenic bacteria, which were accepted as a matter of course.

Special field sampling equipment was employed for taking bacteriological, dissolved oxygen, B.O.D., and chemical samples for laboratory analysis. The refrigerated bottles of water and wastes were transported to the Cali water works laboratory for immediate examination. Samples that could not be analyzed in Cali were flown to the National Sanitary Laboratory of the Ministry of Hygiene in Bogota, where the laboratory work was terminated. Standard methods and modern scientific laboratory equipment were employed in performing the analysis of the various cane wastes, river waters, and sewage samples.

The field investigations indicated that sugar mills were the responsible agents for the pollution of the Parraga and Guabas Rivers. Because of the discharge of the sugar cane skimmings (cachaza) and plant wash water, the Parraga River samples had a B.O.D. of more than 113 p.p.m. It was found that the Castilla sugar mill supplied over one-half the low flow of the Parraga River. Similarly, although the Pichichi sugar mill attempted to control its industrial waste waters by lagooning and irrigation, at certain times in the past there had been overflows which had contaminated the Guabas River basin.

The city of Cali discharges raw sewage into the Cali River in volumes great enough so that it represents 50 per cent of the low flow. However, the details on sewage pollution of the Cauca Valley are outside the scope of this paper.

Besides the sugar mills mentioned, other sugar cane plants surveyed included Manuelita, Mayaguez, and Providencia. Numerous small and old-fashioned cane mills were also visited, but it was found that they do not present a pollution problem because of non-wasteful operating practices.

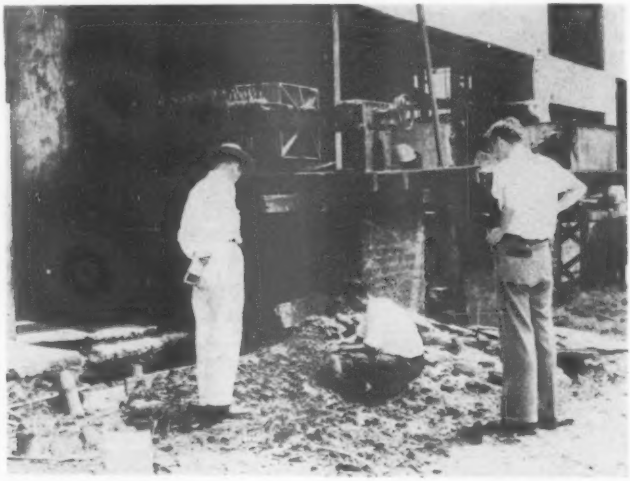

FIGURE 2.—Some mills reclaim sugar from cachaza in filter presses. Cake is returned to fields as fertilizer.

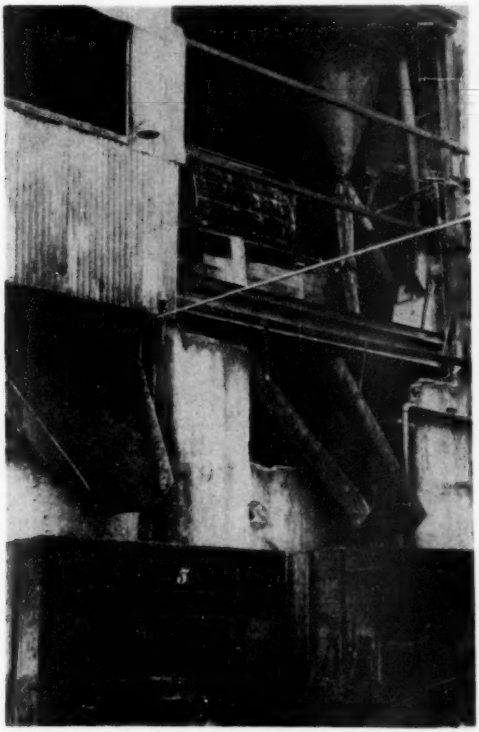

FIGURE 3.—Reclamation of sugar from cachaza by vacuum filters permits chuting of cake to open cars for disposal in fields as fertilizer.

Laboratory Results

It was found that the industrial waste waters of the modern sugar mills varied in B.O.D. content from 140 to 1,120 p.p.m. This effluent could be maintained at lower B.O.D. levels by more efficient plant operation, including the reclamation of sugar from cachaza through filtration (Figures 2 and 3). For example, the Castilla sugar mill wasted more than 440,000 lb. of sugar a year through direct disposal of the cachaza into the waste-water effluent. Similarly, the high B.O.D. of the Pichichi mill waste effluent is indicative of huge sugar wastage.

Besides cachaza, valuable molasses is sometimes wasted. The cachaza had a B.O.D. content in the range of 85,000 p.p.m., but the molasses B.O.D. was more than ten times as great with 930,000 p.p.m. The strong pollution possible from such materials is evident. It also is interesting to note the presence of grease in some of the samples (10 to 6,640 p.p.m.): the grease can be explained as the result of wastage from machinery lubrication in the sugar manufacturing plant. Table I contains a short summary of important laboratory analyses of samplings.

The operating efficiency will determine the amount of water required by a sugar mill to process a stated quantity of sugar cane. The more efficient plants require less water (1.32 to 1.55 c.f.s. per 100 tons of sugar

TABLE I.—Summary of Important Chemical and Bacteriological Analyses of Sugar Mill Wastes and Receiving Waters

Mill	Sample	B.O.D. (p.p.m.)	Total Solids (p.p.m.)	*E. coli* (M.P.N./ 100 ml.)	Grease (p.p.m.)
Castilla	Cachaza and waste water	473	917	—	10
	Parraga River, upstream	—	261	3,800	—
	Parraga River, downstream	113	361	9,500	—
Pichichi	Waste water	1,120	2,302	—	457
Mayaguez	Waste water	140	144	—	0
	Cachaza	84,700	178	—	—
	Molasses	930,000	—	—	—
Providencia	Waste water	250	—	1,300	—
Manuelita	Waste water	—	290	—	—
	Molasses	—	165,970	—	6,640

cane) than the less efficient plants (1.77 to 2.64 c.f.s. per 100 tons of sugar cane). Similarly, whereas the inefficient mills will produce 8 tons of sugar and 1.4 tons of molasses per 100 tons of raw cane, the more efficient mills will produce 12.5 tons of sugar and 2.5 tons of molasses per 100 tons of raw cane (see Table II).

Summary and Conclusions

1. Samples of sugar mill waste effluents contained from 140 to 1,120 p.p.m. B.O.D., depending on the operating efficiency of the plant. An efficient sugar mill utilizes and conserves almost all the sugar, by-products, and waste water, resulting in minimum pollution of surface waters.

2. Sugar mills should filter the high B.O.D. cachaza waste skimmings, so as to reclaim the sugar and fertilizer available. This cachaza has a B.O.D. of about 85,000 p.p.m.

3. Molasses should be used for cattle feed, or in the production of alcohol and other by-products, rather then wasted to streams. Molasses B.O.D. is greater then 900,000 p.p.m.

4. Sugar mills should be located so that the waste waters can be employed to irrigate the surrounding cane fields.

5. The squeezed cane stalks are available for fuel to provide power and heat in the sugar mill. The ashes and filtered cachaza wastes are excellent fertilizer for the cane fields.

6. It is economically advisable to conserve the valuable cane sugar and by-products, rather than to dispose of them into and pollute the neighboring streams. Sugar cane waste pollution is the result of poor plant engineering and/or bad mill operation.

TABLE II.—Comparison of Sugar Mill Operation Characteristics

Mill	Production per 100 Tons of Cane (tons)		Water Use per 100 Tons of Cane (c.f.s.)	Molasses per 100 Tons of Sugar (tons)
	Sugar	Molasses		
Castilla	8.0	1.4	1.77	17.5
Providencia	12.5	2.3	1.33	18.5
Pichichi	9.9	2.5	2.63	19
Mayaguez	10.0	0.8	—	8
Manuelita	12.5	1.6	1.55	12.8
Average	10.6	1.7	1.82	15.2

Acknowledgments

The help of many Colombian engineers including the assistance of officials of the Colombian Ministry of Hygiene and the Institute of Inter-American Affairs is acknowledged. Particular thanks are due Dr. Hernando Correal, chief, National Sanitary Laboratory, who supervised the analytical laboratory work, and Manuel Escalon, Sanitary Engineer, who helped in the field sampling and correlation of data.

A PROPOSED TOXICITY TEST FOR INDUSTRIAL WASTES TO BE DISCHARGED TO MARINE WATERS

By F. M. Daugherty, Jr.

Marine Biologist, Marine Laboratory, Texas Game, Fish and Oyster Commission, Austin, Tex.

As war and population pressures become greater, new areas are being industrialized. This necessary influx of industry into the coastal regions of the country presents a threat to many natural resources, marine in particular.

Most of these industries use large quantities of sea water in some manner: as a coolant, as a source of certain metals, or for disposal of wastes. All of these uses change sea water to some extent and may have a toxic effect on marine life. Process wastes are one of the problems of such industries, for in many cases they cannot be converted economically into a marketable product and must be disposed of via the sea. It is possible to render toxic wastes harmless by dilution with sea water. The determination of safe disposal levels is the problem dealt with herein.

It would be desirable to adopt a standard procedure for determining safe toxic levels of industrial effluents. The cost of such a determination is important both from a monetary standpoint and an economy of time. A test of this type should be easy to set up, easily observed, and should establish toxic levels directly. With an inexpensive, easily operated test it would not be necessary to standardize temperatures and test water, but only the basic procedures and the test animals.

Test animals should be limited to a single species of fish that is widely distributed, easily obtainable, very abundant, and of median to low resistance to toxic substances.

Procedure

The recommended testing setup is very simple, consisting of seven or eight large aquaria of 30- to 50-l. capacity. Junk battery jars serve the purpose very nicely and offer excellent visibility. An oxygen supply can be obtained from any regular laboratory air line or by using a small portable compressor. Air lines may be of rubber or plastic tubing with stone diffusers. Covers of cheese cloth, gauze, or small mesh netting should be used to prevent fish from jumping out or into another aquarium. As stated above, such factors as water and temperature should vary with the area of operation and the existing air temperature. Fish should undergo an acclimatization period of 24 hr. in an aquarium filled with the water to be used in the test. This time is usually sufficient to eliminate injured or sick fish, and neither feeding nor water changing is necessary. The water should be an accurately measured volume which will be convenient in preparing p.p.m. test concentrations. Recently caught fish of the same species should be used for all tests, with 8 to 10 specimens in each aquarium. Air diffusers are adjusted to insure an adequate, but not excessive oxygen supply.

After the acclimatization period, one aquarium is designated as a control and the test material is introduced to the others in a series covering the expected tolerance limits; for example,

10, 20, 30, 40, 50, 60, and 70 p.p.m. A temporary increase of the air volume will cause sufficient agitation to insure thorough mixing. Observation begins immediately, listing the time of each death and noting any unusual activity or inactivity. The test is carried on until no deaths have occurred for a 24-hr. period. Deaths after this period can usually be traced to other causes.

Tolerance limits may be narrowed by setting up a second test system with a series of dilutions ranging from the greatest concentration in which no deaths occurred to the least concentration in which deaths occurred. For example, if in the above series no deaths occurred in 20 p.p.m. and all specimens died in 30 p.p.m., then a system with 21.0, 22.5, 24.0, 25.5, 27.0, 28.5, and 30.0 p.p.m. could be run in order to narrow the tolerance limits. It would seldom be necessary to narrow tolerance limits when concentrations are as high as those of the example, for the dilution factor would not be great. In cases where toxic limits fall at less than 10 p.p.m. it would be desirable to narrow the limits, for the dilution factor would be great.

Once the toxic limits have been established, a safe dilution level for effluents can be determined. The safe level is the greatest concentration at which no deaths occurred. If the data in the above narrowing example revealed that no deaths occurred at 24.0 p.p.m.; then the safe dilution level would be 24.0 p.p.m. At this safe level all fishes of greater resistance than the test species would be more than safe, those of equal resistance would survive without difficulty, and those less resistant would in all probability be safe with the further dilution factor of the effluent mixing with the sea water in the disposal area.

Proposed Standard Fish

Lagodon rhomboides (Linnaeus) was picked as the proposed standard fish for testing industrial waste effluents, for it satisfies all of the criteria previously mentioned. It is widely distributed, very abundant, easily obtainable, and occupies a position of predominantly less to equal resistance with other common species (Table I). Throughout its range this fish is known by many confusing common names, including pinfish, salt-water perch, sailor's choice, robin, salt-water bream, squirrel fish, porgy, scup, yellow-tail, shiner, chopa spina, pig-fish, bream, porgee, fairmaid, and pin perch.

TABLE I.—Comparative Resistance of *Lagodon rhomboides* and other Fish Species Used in Oil Well Drilling Compounds Toxicity Tests (5)

Species	Less Resist.	Same Resist.	More Resist.
Galeichthys felis	4	8	19
Mugil cephalus	2	4	5
Orthopristis chrysopterus	7	3	3
Archosargus probatocephalus	1	0	4
Cynoscion nebulosus	11	8	6
Sciaenops ocellatus	1	1	3
Micropogon undulatus	5	3	2
Menticirrhus americanus	1	1	1
Pogonias cromis	0	2	2
Leiostoma xanthura	3	0	0
Fundulus grandis	0	0	1
Cyprinodon variegatus	0	0	1
Penaeus spp.	8	7	10
Callinectes sapidus	1	2	4
Ostrea virginica	1	8	22
Total	45	47	83

Lagodon rhomboides ranges along the Atlantic and Gulf coasts from Cape Cod to Mexico and to Bermuda and Cuba (1). It is common from Virginia southward (2). Goode and Gill (3) state that this fish is exceedingly abundant south of Cape Hatteras. Thus, it may be noted that this fish has a very extensive range and over much of its range is very abundant. That *Lagodon rhomboides* is found in Texas waters in great abundance is the personal observation of the writer, and it is known by the thousands of sports fishermen as the number one bait stealer.

This fish is readily available, being easily captured by shrimp trawl hauls of short duration, by baited trap, and by pole and line. Fish taken by the last two methods are best for test purposes, for they are less apt to be in-

jured than those caught by trawling. Trapping is favored by the writer, for a large supply is usually found close-at-hand around piers and wharfs. These fish are present in Texas bays throughout the year, scattered during the warm months and concentrated in deep water during the cold months. They are very adaptable to physical conditions, for they have been found in temperatures ranging from 9.1° to 34.9° C. and in salinities of 2.1 to 37.2 parts per thousand (4).

The comparative resistance of *Lagodon rhomboides* with other common species (Table I) was determined by the writer in a series of tests on oil well drilling compounds (5). As previously stated, it occupies a position of less to equal resistance with other common species. In the tests of oil well drilling compounds it was found to be either less or equally resistant in 130 cases and more resistant in 45 cases.

In one series of tests run by the writer, 117 *Lagodon rhomboides* were measured. These fish ranged from 57 to 113 mm. standard length, with a mean of 93 mm. Fish of this size are good for aquarium testing, as a 30- to 50-l. aquarium can support 8 to 10 of these fish without crowding.

Summary

1. A simple and inexpensive test of short duration is recommended. It is easy to set up, easy to observe, and establishes toxic tolerances directly.

2. Basic procedure and test animals are standardized, but not the constituents of the water or its temperature.

3. *Lagodon rhomboides*, the standard fish, is distributed abundantly from Cape Hatteras to Mexico, is easily caught, and occupies a position of low to median tolerance to toxic materials.

4. This is a test that can be run as conditions and/or effluents vary.

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TREATMENT OF CHROMIUM WASTES BY ION EXCHANGE [1]

By Richard G. Tyler, William Maske, and Milton J. Westin

Professor of Sanitary Engineering, Research Chemist, and Research Fellow, respectively, University of Washington, Seattle, Wash.

The sanitary engineering staff of the University of Washington has been engaged in cooperative research with the Washington Stream Pollution Control Commission for the past two years, during which time it has investigated several of the industrial waste problems that are of interest to the Commission. One of the projects suggested for study by E. F. Eldridge, director and chief engineer of the Commission, was to investigate the treatment by ion exchange of chromium wastes from metal treating plants.

Bloodgood and Strickland have discussed (1) the complexity of chromium in its manifold combinations, together with its peculiar behavior in ion exchangers. An investigation was therefore initiated as to its behavior, first in a cation exchanger, and later with activated carbon. This paper deals with two aspects of the observed reactions. The first or major problem has to do with what takes place in the exchanger; the second is confined to a brief comment on the effect of this treatment in controlling stream pollution.

Zeo-Karb Tried

Zeo-Karb H was selected for the first part of this study because Zeo-Karb Na had proven very satisfactory in an earlier study by the senior author on sulfite waste liquor, a strong, acid waste from the pulp and paper industry. It was hoped that Zeo-Karb H would be equally rugged and effective with chromium wastes. This turned out to be a happy choice, as a few runs on a styrene base exchanger later in the study produced a heavy color throw, indicating that a breakdown of the exchanger was taking place.

There was nothing unusual in the method of operating the exchanger except that it was soon realized that better results were obtained by acidifying the Zeo-Karb before applying the chromium. The full significance of this behavior was not recognized until it became apparent that reactions other than ion exchange were taking place. Chromium storage occurred in the exchanger, as mentioned by Bloodgood (1). There was a build up of chromium in the Zeo-Karb to a concentration of from 0.1 to 0.3 per cent of the weight of the latter, after which a greater recovery of chromium was obtained.

The results obtained by this exchange process can be illustrated best by indicating the results obtained from two test series. In Series 2, with 0.3 per cent accumulation of chromium in the bed, the average chromium recovery for five runs was 95.65 per cent. During the prior five runs, while chromium was being stored in the bed, the recovery was only 36.3 per cent. In Series 5, similar recoveries reached 92 per cent for the last seven runs, after averaging 69.1 per cent recovery during the first seven. The stored chromium in this case was under 0.1 per cent of the weight of the exchange material. There was a wide variation in the results of individual runs, which was another indication that some factor other than ion exchange was influencing the results quite erratically.

[1] Research sponsored jointly by the Engineering Experiment Station, U. of W. and Washington Stream Pollution Control Commission.

The change of valence reported by Bloodgood also took place in these runs, in that the hexavalent chromium was reduced to the trivalent form. This, together with the beneficial result of pre-acidification mentioned above, indicated that reduction of the chromium was taking place through the oxidation of some of the exchange material. A series of 15 runs was therefore made, utilizing heavy dosages of 670 p.p.m. chromium, whereas the above runs were made with concentrations of 8 to 60 p.p.m. Regeneration during this endurance test was with 25 per cent H_2SO_4, whereas during the regular runs 4 per cent acid was used. Although no observable loss was obtained, it was obvious that some breakdown must be occurring, but was probably obscured by some compensating error.

In spite of the fact that no appreciable change in weight was taking place, it seemed probable that under the conditions of these tests the Zeo-Karb was not acting as an ion exchanger, but as a reducing agent. In that case, an equivalent oxidation would have to take place in the exchanger to balance the reduction in valence of the chromium. A. B. Mindler, of the Permutit Company, confirmed this theory and stated that Zeo-Karb possessed some of the properties of an activated carbon.

Activated Carbon Used

In order to throw more light on this point, several runs were made in which Carbo-Dur, an activated carbon of high capacity, was substituted for Zeo-Karb H. These experiments were exploratory rather than detailed, but the results obtained confirmed previous suspicions and considerably clarified our understanding of what was taking place.

The following comments summarize some of the results from these tests.

1. With no prewash, Carbo-Dur took up 2 per cent of its own weight of chromic acid, expressed as chromium trioxide (CrO_3). But with a prewash containing 5 per cent of sulfuric acid, about 5 per cent of chromium trioxide was taken up. With a prewash of 5 per cent of potassium hydroxide, about 3 per cent of CrO_3 was absorbed.

2. If the carbon is prewashed with sulfuric acid and then thoroughly irrigated until the washings no longer give cloudiness with barium chloride, then when chromic acid is run through it the effluent will again contain sulfuric acid even when the carbon will have become nearly saturated with chromium.

3. If acid is used for regeneration, the recovered chromium will be trivalent, but if alkali is used, the chromium will be recovered in the hexavalent form. From other experiments, which will be more fully discussed in a future publication, it appears that, in order to regenerate an anion exchanger with acid, free carbon or some other oxidizable substance must be present to compensate for the reduction of the chromium to the trivalent form.

4. On the initial regeneration most of the chromium can be recovered, but an excessive amount of the regenerating reagent is required to get it out.

5. With acid regeneration, carbon dioxide is produced in the exchanger.

Experimental Observations

From these observations the following conclusions can be drawn:

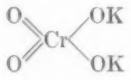
1. Inasmuch as the chromium can be taken up and the regeneration carried out either with acid or alkali, and as a large excess of regenerating reagent must be used, it is apparent that the catalytic carbon acts as an adsorption, rather than as an ion, exchanger.

2. In prewashing the carbon, adsorption of acid or alkali takes place, depending on which is being used in the prewash. If chromic acid is run through two such exchangers, the first of which was prewashed with alkali and the second with acid, different reactions take place. In the first one, the alkali and the chromic acid combine to form a metallic chromate. On regeneration, this chromate is displaced by

alkali. In the acid prewashed exchanger, no reaction would take place between the regenerative acid and the chromic acid, but the latter is replaced by the former. On regeneration, replacement again takes place, but in the opposite order, in that the chromic acid is now replaced by the regenerative acid. It is possible, also, that because the alkaline chromate is a larger molecule than chromic acid, this may account for the Carbo-Dur taking up 5 per cent of its weight of chromic acid with an acid prewash and only 3 per cent with an alkaline prewash.

3. It is a well-known fact in physical chemistry that when activated carbon is washed successively with two different reagents (in this case chromic and sulfuric acid) eventually an equilibrium will be reached, after which no more of the first reagent will be removed, regardless of how much further washing with the second reagent is done. This explains why some chromium will be stored for the first few cycles before the output will approximate the input.

4. As previously mentioned, acid regeneration will yield trivalent chromium, whereas alkaline regeneration will yield hexavalent chromium. In order for chromium to combine wth sulfuric or any other acid it must be in the trivalent form to form its salt, $Cr_2(SO_4)_3$. With alkaline regeneration, for the formation of an alkaline chromate or dichromate, such as K_2CrO_4 or K_2CrO_7, the chromium must have a valence of six, as shown by the structural formulas



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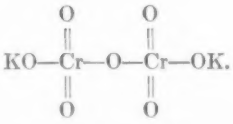


Therefore, the valence of the recovered chromium is governed by whether the regenerating reagent is acid or alkaline.

5. For the reduction of valence from six to three, which occurs with acid regeneration, there must be an equivalent oxidation of some of the exchange material. It is not difficult to prove that in this case the free carbon is oxidized to carbon dioxide. That such a reaction actually occurs can be seen in the procedure used in most laboratories for cleaning mortars and pestles that have become soiled with carbon. They are soaked overnight in "cleaning fluid" which is a mixture of chromic and sulfuric acids, the same reagents involved in the exchanger. By the next day the carbon will have disappeared through oxidation, the equipment is clean, and the cleaning fluid will have some of the characteristic greenish color of trivalent chromium.

Because the chromium in the acid exchanger becomes trivalent upon regeneration and because carbon dioxide also is evolved, it is obvious that an oxidation of some of the carbon must have taken place. To confirm the necessity for an acid medium, a mortar dirty with carbon was soaked overnight in a mixture of potassium dichromate and enough potassium hydroxide to give a strong alkaline reaction. Next day the carbon was still present and there was no greenish color to the liquid. Thus, the chromium was still hexavalent and no reduction had taken place, just as was the case in the alkaline exchanger. This simple qualitative test duplicates the reactions in the Zeo-Karb and Carbo-Dur and is used to illustrate these reactions, as they are so well-known to chemists.

The loss of carbon from the adsorber may not be too serious a matter from a cost standpoint. From equations previously given, a few calculations reveal the fact that for every 400 lb. of chromium trioxide reduced, only 36 lb. of carbon would be required for oxidation losses. At a cost of 10¢ per pound for the activated carbon, the loss from oxidation would be less than 1¢ for each pound of chromium trioxide reduced.

Furthermore, if a concentrated chromic acid solution is applied to an alkaline prewashed activated carbon, before the latter becomes saturated the predominance of acid will reduce some of the chromium, even when alkali is used for regeneration. This behavior was checked experimentally; on regeneration hexavalent chromium contaminated with trivalent was recovered.

The valence changes, for acid regeneration, can be postulated as follows:

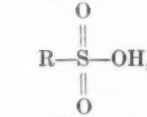
$$4\overset{+++}{Cr} + 3C \rightarrow 4Cr^{+++} + 3C^{++++} \quad (1)$$

Or, using sulfuric and chromic acids, Eq. 1 becomes

$$6H_2SO_4 + 4H_2CrO_4 + 3C \rightarrow 2Cr_2(SO_4)_3 + 3CO_2 + 10H_2O \quad (2)$$

In addition to the valence changes, which are the same in both equations, a considerable amount of dehydration is also indicated, as 10 molecules of water are formed.

The foregoing discussion clarifies the observed behavior of the Zeo-Karb H exchanger. This material is prepared by treating a special coal with fuming sulfuric acid. In this treatment, organic matter in the coal is sulfonated and much of the free carbon is activated. The sulfonated material can be represented empirically as



sulfonates with trivalent chromium, but apparently should not form sulfochromates or dichromates with hexavalent chromium. This was confirmed by test tube experiments, in which benzene sulfonic acid (benzene sulfonate) was mixed with chromium sulfate (trivalent) in one tube and with potassium dichromate (hexavalent) in the other. As was anticipated, the sulfonic acid reacted with the trivalent, but not with the hexavalent chromium.

Hence, if trivalent chromium is run through Zeo-Karb H, the latter will act as a true cation exchanger by replacing the hydrogen in the sulfonate radicals with chromium. But it cannot act as an anion exchanger; hence, if hexavalent chromium is used, it will function rather as an adsorber because of its activated carbon content. On regeneration with acid, the chromium will be reduced, an equivalent amount of carbon will be oxidized, and some of the chromium will be regenerated as an acid salt.

The reactions involved in treating chromium wastes by ion exchange have been discussed in detail in this paper because the sanitary engineer, who is interested in the treatment of this waste, is less familiar with the various reactions which may occur than is the chemical engineer or sanitary chemist. Studies using anion exchangers with this waste will be discussed in a subsequent paper.

Effect on Stream Pollution

In concluding the present discussion, however, the effect on stream pollution of the treatment heretofore discussed should be mentioned, as that was the primary reason for initiating these studies. Where the chromium is not to be recovered, but is to be discharged to a stream, the reduction of the chromium from the hexavalent to the trivalent form reduces its toxicity by about 99 per cent. This will satisfy stream pollution requirements except where excessively strong wastes are involved. The large quantities of acid required for regeneration, unless other wastes of an alkaline nature are available at the plant for neutralization, will in themselves produce a pollution problem that might violate local stream standards.

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Stream Pollution

FLEXIBILITY IN INDUSTRIAL POLLUTION CONTROL ADMINISTRATION *

By L. L. Hedgepeth

Technical Consultant, Calco Chemical Division, American Cyanamid Company, Bound Brook, N. J.

The pollution abatement movement in the United States arises from the conviction of a majority of the people that the streams must be cleaned up in the public interest. In the case of sanitary sewage, the technical know-how is possessed and the problem is resolved into one of municipal financing. In the case of industrial wastes, much progress has been made in acquiring the necessary known-how for getting the job done. There is, however, much to learn before abatement of all industrial pollution can be a reality.

In both cases, municipal and industrial, the job is costly—so costly that there must be no question about the necessity of securing the abatement of stream pollution. If there is any doubt about this, the heavy investments required will not be made. Nothing short of an absolute requirement to abate pollution will do the job that must be done. In addition, this must be applied with due regard for practicability and for the equities involved. The question of the need of stream pollution control legislation may be disposed of, therefore, by observing that it is essential in order to secure the required abatement.

On the premise that an absolute requirement for pollution abatement is a regulatory "must," this author's feeling about governmental control is that the complex problems of industry should be differentiated into their related parts, rather than integrated into standardized categories. It is realized that able and conscientious workers take the opposite view, but the author is sustained in his conviction, and is prepared to defend it, vigorously if necessary, by the realization that there is no universally applicable yardstick with which industrial pollution may be measured.

It has been previously observed that this picture is complex—so complex that it is not good workmanship to reduce the problem by mathematical bulldozing with a common denominator. Toxicants, acute and chronic in varying degrees, dyes, acids, alkalies, sludges, oils, tars, resins, fungicides, pharmaceuticals, insecticides, pigments, odorous materials, and other types of wastes are too complex to be forced into generalized summaries. Yet, in such a plant, making a thousand different products, causing hundreds of differing types of wastes, one is today faced with the impossible task of framing truthful descriptions of such wastes in a few lines of official questionnaires. The author confesses that he is perplexed and confused by such documents.

Irritation with such approaches is an emotion which is not helpful in

* Presented at 1950 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 23–25, 1950.

this matter of conflicting interests. It appears timely, however, to observe that the forcing of the industrial waste situations into predetermined forms will merely result in such oversimplification that the pattern will become obscured and the perspective thrown out of focus.

Industry in general, at least that portion of industry with which the author is familiar, recognizes that it has this waste clean-up job to do. Observations from several years of experience with this problem in the chemical industry are that management is aware of the necessity of doing the job. This is because the several state and federal laws spell out in differing languages the common theme that stream pollution is against public policy. And, as Murdock (1) has observed, public need of water supply may cause a polluter to be compelled to correct his ways even though the cost of such correction ruins his business. This principle that public need of water resources transcends private rights is well accepted and wise management recognizes stream pollution abatement as a present day "must."

However, merely deciding to do this job is only the first step; more important is the second step—how to do it. It is felt that the regulatory authorities should recognize and become familiar with the complexities of the modern industrial establishment and, in so doing, become intimate with each significant problem under their jurisdiction.

The large chemical plant of today is a lace-work of related processes, yielding products, co-products, and by-products in varying ratios. Also, in varying degrees, there issues from these processes the air- and water-borne materials which are given the generic terms of "air pollutants" and "industrial wastes." Previously, before the relatively recent requirements for pollution controls, the planning of such processes has been influenced by the adage of the chemical engineer: "Air and water are the cheapest raw materials."

Few, if any, pollution abatement steps have been designed into the processes. In such a plant, successful pollution abatement programs require pollution prevention awareness all along the line. Research must plan for it when devising processes for new or improved products; the engineers must make provision for it in the equipment design; the shift operators must avoid sewering pollutants whenever possible, thus reversing the old tendency to consider those wastes which are out of sight down the drain as being out of mind; the service group must operate the waste treatment facilities conscientiously; management must spell out and encourage a good neighbor policy; and, most important, the policy of the regulatory authority having jurisdiction should be flexible so as to recognize that pollution reduction, however obtained, is the real goal.

Success in this field can be measured only in terms of pollution reduction. The mere appropriation of money will not solve this problem and too often it has resulted in a short period of successful feeling, later followed by the bitter realization that white elephants have been built as an offering to the engineering idol of standardized judgment.

Regulatory agencies are urged to approach their responsibilities with an informed technical intelligence and a flexible program, coupled with an absolute requirement for pollution to be brought down to the assimilation levels of the streams.

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THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

BUSMAN'S HOLIDAY

Housewives learn most of the tricks of their trade by what to most baffled males seems like idle chatter during backyard conversations and telephonic exchanges of "intelligence." However, this informal method of exchanging notes on household operation, maintenance, and experimentation permits of broadening one's viewpoint on these very matters beyond that obtainable by being a stick-in-the-mud stay-at-home.

How this type of over the fence education can benefit a treatment plant operator is discussed by Superintendent R. W. Frazier, of Oshkosh, Wis., in an editorial in the December, 1950, *Wisconsin Clarifier*. Mr. Frazier makes the point that a trip to other treatment plants will give the visiting operator a better idea of treatment plant operation by being able to see the different types of operation and discuss with other operators the problems peculiar to their plants. The exchange of ideas will prove of benefit to both visitor and host.

Another opportunity for exchange of information on an informal basis is offered by operators' conferences and association meetings. Quite often an operator finds the answers to his problems and questions through contact at these meetings with other operators—even, sometimes, of plants quite dissimilar from his own.

The main point is to get away from the "hot stove" of one's own plant and meet with fellow operators. In your own city there usually is only one treatment plant and you are responsible for its operation. The opportunity to visit with the neighbors and talk shop with others who speak the language is unsurpassed in value received. The comparisons afforded give one a basis for going back home and trying to improve his own operation. If you think that you have troubles, you'll always find someone with worse troubles; if you're feeling somewhat smug about the excellence of your operation, you'll find someone who's doing better.

Remember that for every item found in print about practical operational ideas, kinks, or gadgets, hundreds are buried in the experience of these fellow workers who have felt in the past that they just didn't have the time to write about them. Often an operator will spend hours talking with you about these gems of ingenuity and ability, but will neglect to spend the few minutes required to record them for contemporaries or posterity. This hidden store of knowledge is the substance of which operational improvements are made, and time spent objectively in finding out what other operators are doing is time well invested.

H. P. O.

OPERATION DIGESTER CLEANOUT

By J. E. Meers

Chemist, Danville (Ill.) Sanitary District

In July, 1950, after 13 years of continuous operation, it became necessary to completely dewater and clean the digestion tank at the Danville (Ill.) Sanitary District sewage treatment plant. Despite thorough preparations against any and all contingencies, "Operation Cleanout" was tackled with considerable reluctance. However, once the attack was mounted it was carried out to a successful result without any undue setbacks. How it was done may be of interest to other operators facing the same problem.

The 600,000-gal. digester, equipped with steel floating cover and internal heating coils, had showed some loss of heat exchange efficiency and a loss of useable volume by reason of solids deposited in the bottom. To restore it to good condition it became apparent that it would have to be cleaned out, which would also give an opportunity to check the interior for the first time in the tank's 13 years of service and repair any damage to such vital parts of the original construction as brackets, braces, heating coils, temperature control units, and meter controls.

So much had been read in the literature and heard in operator discussions about gas explosions, covers dropping, men slipping or falling, oxygen depletion, pump accidents, and the like, that precautions were taken against every foreseeable happening. Thorough discussion of the problems to be encountered prepared the personnel involved for the task at hand and refreshed memories on rescue techniques and emergency procedures. Happily, these were not needed.

The following is a condensed day-by-day account of the work:

July 3—Active preparations for the dewatering were started, with sludge samples being taken from the digester and from the sludge storage tank. No supernatant liquor will be drawn from the storage tank, as this tank is to be more fully filled in preparation for pumping raw sludge from the settling tanks in a few days. The drying beds were being readied for receiving digested sludge from the storage tank.

July 4—Results of the samples taken on the 3rd showed 11.9 per cent dry solids and 33.3 per cent volatile solids in the digester, with 11.7 per cent dry solids and 36.5 per cent volatile solids in the storage tank. An electrician has been engaged to install a 220-v. receptacle tomorrow for the air blower that will be used to force the gas from the digester.

July 5—The night operator reported that one of the sludge pumps was out of order and could not be used. In removing the pump for repairs at the machine shop, the 6-in. gate valve next to the pump was found to be broken and had to be replaced. Half of the concrete blocks (56) on the top of the digester floating cover were set on the wall, as it was felt that the brackets would hold the weight of the cover and half of the ballast. After the blocks were moved a start was made on lowering the digester contents by pouring digested sludge from the bottom.

July 6—The work of lowering the digester proceeded slowly but satisfactorily. An oil burner was placed in the boiler to supply heat during the time the gas will be low after the tank is restored to operation. Also, the men hauled sludge from the drying beds to make room for more sludge, either from the digester or the storage tank. No supernatant has been drawn as yet from the storage tank, which this morning stood at 17 ft. 2 in. (it is pro-

posed to carry this tank at about 19 ft.) The repaired sludge pump was returned from the machine shop and put into service by 2:30 P.M. The other sludge pump was started at 11 A.M. to pump sludge to a shallow lagoon on low ground on the plant property.

July 7—The trouble with the 6-in. gate valve at the first sludge pump prompted a check of the one serving the second pump. It also needed repairs. The digester cover was down on the brackets and a nozzled fire hose was brought into use to wash the sludge toward the sump. By 2 P.M. the sludge was down to the top of the heating coils and stopped pumping to the lagoon. Effective use of the hose soon started it flowing again, with the intention of pumping all night, if possible.

July 8—A 10-ft. length of 2-in. pipe with an elbow on the bottom end was connected to the hose, making it easier to control the flushing operation on the floor of the tank and keep pumping rather heavy sludge. The repaired gate valve was replaced in the afternoon so both pumps were again available.

July 9—Pumping of the tank was continued, using the hose intermittently all during the day. Two of the heating coils on the west side and one on the east side were exposed. It was necessary to draw supernatant from the storage tank for the first time—10,300 gal. and dark.

July 10—Pumping and use of the fire hose was continued. One of the men found a black snake about 5 ft. long on the digester cover this morning. It probably crawled up the ivy vines on the side of the tank. After a little excitement it was killed. About 5 to 6 ft. of sludge still remained in the tank and it was becoming more and more difficult to pump. There was still quite a bit of gas and considerable heat was forced out of the manholes whenever the hose was in use.

July 11—Pumping was continued, with quite a volume of rags and grit involved.

July 12—Most of the day was spent in placing on the cover a force pump rented from a local contractor. This was necessary because our own pumps could not lift all the grit and scum out of the bottom of the tank. The heavy sand and grit content of the remaining sludge made it hard to get away from the tank sides.

July 13–16—Washing and pumping, although continued, made slow headway. There was no evidence of gas in the tank. The force pump seemed to operate satisfactorily, but large volumes of water were needed to move the sludge at all.

July 17—All the heating coils have been exposed. Although there was some evidence of thin scale on the coils it appeared easily removable with hammers.

July 18–19—Pumping continued, with slow progress. The brackets holding the sludge intake pipes seemed to have dropped, but thorough investigation was left until later.

July 20—The outer edge of the tank floor was exposed, although the sludge was piled about 3 ft. high around the heating coils. Every bit had to be washed to the center with the hose, inch by inch, and a stream of water was necessary near the pump intake to break the heavy solids for pumping. About half the material from behind the coils was washed down to the center.

July 21—The remainder of the sludge was washed to the center of the tank. Three of the pipe supports for the 6-in. discharge line were found out of place (Figure 1). The 2½-in. heating coil pipes were found in very good condition, the thin scale on them being easily removable with small hammers. The heating coil support

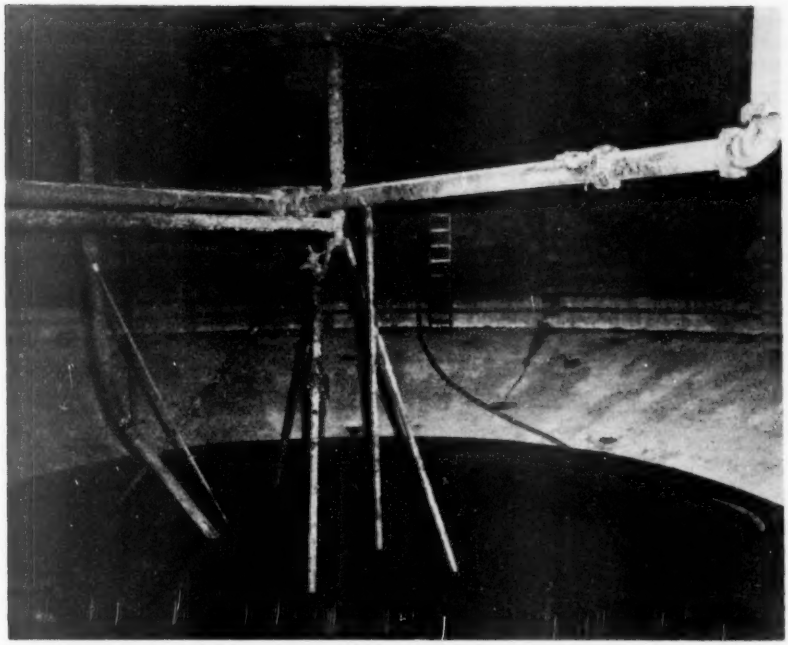

FIGURE 1.—Interior of drained digester showing force pump suction and ¾-in. water line to agitate sludge and grit around pump suction (through sampling well at upper left); sludge inlet piping supports fallen out of place (center); and access ladder and fire hose used for washing heavy deposited material to center (background).

brackets, the concrete, and the metal work were all in good shape and showed no signs of deterioration.

July 22—Practically all the solids had been removed from the tank, including large amounts of sand found near the center. Further examination of the supports of the 6-in. discharge line showed them held in place on the floor by a bolt and nut over which the hollow support end was slipped, and placed under the discharge pipe with a half-collar arrangement. It was decided that a clamp should be placed around the 6-in. pipe at each support to prevent sliding of the support along it.

July 23—Finished pumping from the tank, except for a small quantity of water in the center. Started scaling the heating coil pipe and got about half of it cleaned.

July 24—Finished removing the scale from the heating coils. The scale was about ⅛ in. thick on the botton side of each pipe and about ¼ in. thick on the top side.

July 25—The last water was pumped from the tank and all piping was rechecked to be sure all scale and rust was removed.

July 26—The tank floor was cleaned of all scale, dirt, etc. No attempt was made to pump this debris, all of it being carried out through the cover manholes in buckets. About 1½ cu. yd. were removed in this manner.

July 27—Three new supports, of 2-in. galvanized pipe, were placed under the 6-in. discharge lines.

July 28—The clamps previously decided on were made and placed on the 6-in. line to keep the supports in place. These clamps were made of ¼-in. by 1½-in. copper 12 in. long and were bolted together. After the tank temperature control unit was replaced, a final inspection was made to make sure that nothing had been left in the tank and that all necessary work had been completed.

July 29—Operation Cleanout was completed by reseeding the digester from the storage tank and restoring it to active service after 26 days "out of the line."

CHAIN DRAGS ON DISTRIBUTOR REDUCE FILTER POOLING

By R. Spiess

Superintendent, Sewage Treatment Plant, Litchfield, Ill.

Each year, beginning about the middle of November, the trickling filter at the Litchfield, Ill., sewage treatment plant shows signs of pooling. The condition, which is chronic, becomes steadily worse unless active remedial steps are taken. In general, however, the clogging growth is of the type referred to by one operator as "hog-hide" and affects only the surface layer of the stone.

Several methods of remedying the condition have been tried. Although none has been able to correct the basic cause of the difficulty, which probably is the small size of the filter stone, the method finally chosen is as simple as any and does keep the filter surface reasonably clean.

Shop-Made Chain Drags

The basic elements around which the method is developed are two simple shop-made chain drags that are readily attachable to the arms of the rotary distributor. Each is composed of an 8-ft. length of 1-in. by 1-in. by ⅛-in. angle iron, with setscrew clamps riveted or welded near both ends (see Figure 1) and 18-in. lengths of chain fastened along the angle at 8-in. centers. The entire assembly should be as light as possible to avoid interference with distributor operation.

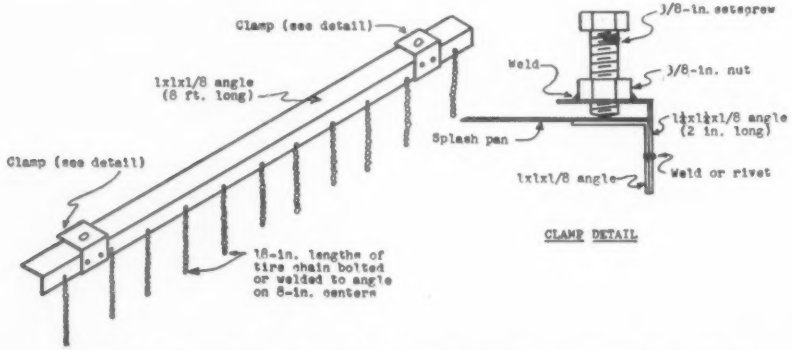

FIGURE 1.—Simple chain drag for cleaning trickling filter surface fastens to distributor splash pan.

Each clamp is made of a 2-in. length of 1¼-in. by 1¼-in. by ⅛-in. angle iron drilled for the ⅜-in. setscrew and with a ⅜-in. nut welded over the hole. The last item is necessary because the angle itself is too thin to provide sufficient grip for the setscrew threads.

The chains are 18-in. lengths of light tire chain. This particular length was chosen to provide about 8 to 10 in. of chain to reach down to the stone, plus an additional 8 to 10 in. in contact with the stone.

How Drags Are Used

One of the drags is fastened to the splash pan at the outer end of a distributor arm. The other is fastened at the inner end of the opposite arm. The chains do not disturb the filter stone, but merely drag or bounce over the filter surface as the distributor rotates, thereby scraping or knocking off the excess surface growth. After the drags have been on for 24 hr. they are moved 4 in., so that the chains are between their original positions. After the second 24 hr. the drags are moved along the arms to cover new areas of the filter, continuing the process until the entire filter has been cleaned. If the distributor seems to pull hard, a few chains are removed from the outside drag. This, of course, will increase the total time required to clean the stone.

The chain drags described were built at a very nominal cost, as most of the materials were salvaged from scrap and assembled in the plant shop.

THE DAILY LOG

Kenosha, Wisconsin

By Frank I. Vilen, *Superintendent*

April 17—Just a month has elapsed since your Logger assumed new duties as superintendent of the sewage treatment plant after 12 years of service as assistant city engineer. This move was made when the former plant superintendent was moved up to superintendent of the Water Department, our parent body. The unusual arrangement results by reason of the sewage treatment plant (officially known as the "Water Supply Protection Works") being a part of the water utility, subject to the State of Wisconsin laws and regulations pertaining to public utilities. (Some interesting advantages accrue from this setup [see This Journal, **22**, 9, 1219; Sept., 1950]—Ed.)

Ours is a primary treatment plant with separate sludge digestion. The design flow is 10 m.g.d. The plant is ideally located on the shore of Lake Michigan, adjoining a public park and bathing beach, and near a first-class residential area. The buildings are architecturally pleasing and well constructed; the structures and equipment are very clean and well maintained. The plant grounds are beautifully landscaped and the whole plant is a credit to the operating staff and to the city.

April 22—An inspection of the engine exhaust chimney revealed that most of the fireclay joints in the 24-in. square flue lining have been completely leached out. This chimney receives the exhaust from the sewage gas engines. No doubt, the failure of the joints can be attributed to the effect of the exhaust gases and condensation.

April 25—Decided to clean and rake out all the flue joints and recaulk with lead wool; also, to extend the flue several inches above the chimney cap, in-

stead of below it as at present. To do this we began the construction of several sections of a narrow iron ladder that can be lowered into the chimney and bolted together as the repairs progress. Also devised a platform to hook on the rungs of the ladder for the workman to stand on.

May 20—The chimney job is finally completed, the final step being the pointing up of the exterior stone facing. During the caulking operations, we could not use the gas engines because of the fumes and all pumping was done with our standby 10-m.g.d. electric motor-driven pump. This was a disagreeable and arduous task in a confined space. Nevertheless, the crew did a good job and all are happy that it is over.

May 22—Surveyed the No. 1 digester. The Kenosha plant has two 70-ft. diameter digesters with floating covers; one is equipped with the gas holder. Digester No. 1 was designed as a primary, but we operate them in parallel. Found about 3 ft. of oily scum on top of the digester; bottom sludges as high as 49 per cent dry solids.

May 25—Large quantities of oil were issuing from the outfall of the storm sewer at the golf course creek. It looked and smelled like a heavy grade of fuel oil. (Subsequent analyses confirmed this.) Contacted officials of the only industry using an oil of this type and they are now busily at work to locate the source. They don't want to lose the oil—we don't want it in the creek—everyone is most cooperative.

June 1—We are still finding intermittent flows of oil to the creek. Working on it.

June 2—A record 3.27 in. of rainfall today. Gas production dropped from 46,000 to 22,600 cu. ft. A rain of this magnitude means about 7,600 gal. of roof water to each digester, or more than our daily sludge pumpage. It must be wonderful to operate a plant with just a sanitary flow! What with storm flows, and ground-water infiltration to leaky combined sewers, we sometimes have plenty of trouble.

June 3—The gas slump continues. Our sewer system is "blessed" with a storm-water impounding reservoir, which is supposed to control the flow from a large area in the southwest portion of the city and thus prevent overloading the sewer system during storms. The impounded portion is then discharged to a trunk sewer and eventually reaches the plant. This increases the load, costs money to pump and process through the plant, occasions trouble with large quantities of grit, and, from our point of view, we could do without it.

June 4—One of the operators took a call from a very agitated lady who alleged that she had dropped a diamond ring down the toilet bowl. Could we find it for her, please? He explained that the possibility of it reaching the plant was most remote, and, of finding it, should it get here, impossible. To pacify her, he promised to be on the lookout, and suggested a check in the plumbing in her home. Of all the miscellany that finds its way down here, diamonds would be most welcome!

The impeller shaft on one of our 10-m.g.d. sewage pumps has broken at the impeller lock nut; a new one is being made at a local machine shop.

June 5—The bottom side of the exhaust muffler was badly corroded. This muffler is 2 ft. in diameter, 9 ft. long, and weighs about 750 lb., and is flange bolted to the exhaust line approximately 17½ ft. above the pump-room floor. It was decided to turn the muffler to place a good side down and thus get more wear out of it. This required building a scaffold to hold the weight while the muffler was loosened and turned, a rather difficult job because of the size, weight, and location. At the same time a better drain system was devised, along with a

means of flushing the drain lines to keep them clear of rust and scale and allow the free flow of condensate.

June 6—"Completely worn out" would describe the condition of the clarifier flight shoes. The angle used in the original shoes was not a standard section and had one leg longer than any currently available. As this leg was not on the wearing face, we purchased a stock angle, cut it into proper lengths, drilled the necessary holes, and proceeded to replace the worn out shoes.

June 7—The rubber chlorine feed line blew out at 10 A.M. The chlorine was shut off with no damage and the break was repaired. A new hose was ordered, as this one looked like its useful life was about over.

A power failure due to a storm occurred from 12:30 to 12:50 P.M. Such an event always is a time of hustle to get the auxiliary gas engine-driven circulating pump into service and to shut off a dozen or so 220-v., 3-phase motors.

June 8—An inspection of the plaster ceilings in the main building, which have just been washed, indicates a need for a paint job.

June 9—Started the annual painting of interior and exterior masonry walls, using white cement and lime. Sludge removal started today from the beds. With uncovered beds, we start the winter with as many empty as possible for filling during the winter months.

A delegation from LaCrosse, Wis., headed by Superintendent Carl Wahlstrom, visited the plant. He is having copper troubles and wants to know of our experience with it.

June 12—Cleaned the flocculator basins today; removed an estimated 25 cu. yd. of fine material resembling foundry sand, which had gotten by the grit removal unit.

Almost from the start of plant operations in 1941, a 99-in. trunk sewer serving a large part of the southwest portion of the city had been by-passed at its junction with our interceptor because of the toxic effect of copper wastes on plant operations. The problem of these wastes has finally been solved by the construction of a private sewer, which discharges them directly into the lake instead of to the treatment plant. Accordingly, the plug which had diverted the flow from this trunk sewer has been removed and we are now receiving all of the city's dry-weather flow. Somewhat less efficient treatment results, of course, as our load has been more than doubled, detention periods have been less, and digester loadings have been increased.

June 17—For the most part, our grit load has been very light (averaging about 1½ cu. ft. per day). With the increased flow, we expected more grit; today it came with a vengeance! Someone had neglected to operate the grit equipment, with the result that it jammed. So we spent most of the day shoveling out about 25 cu. yd. of a fine heavy sand, which the equipment could not handle.

June 24—Cleaned the flocculator tanks of a large accumulation of grit, which had gone past the grit removal equipment. Up to now the operation of the grit machinery has been intermittent and based on the operator's judgment. Henceforth, the equipment will be started at 2-hr. intervals and operated continuously during storm flows. No more shoveling if we can help it.

July 11—Walked to work this pleasant summer morning. The neighbor's wire-haired terrier decided to come along, despite my arguments to the contrary. Seemed to have a mind of its own, but learned a lesson the hard way, for, later on, I found him swimming around in one of the flocculator tanks. There is only about 6 in. of clearance between the tank wall and the mixing paddles and it is a wonder the dog wasn't drowned. Fished him

out with a hook, and he immediately took off for home, a dirtier but wiser dog.

July 17—Today our plant was host to the Wisconsin Conference of Sewage Works Operators. A total of 44 persons enjoyed a buffet lunch at the beach pavilion and spent the afternoon inspecting our treatment facilities. It takes a lot of work to plan a meeting of this kind, but it certainly is worth-while!

INTERESTING EXTRACTS FROM OPERATION REPORTS

"The available tools are only part of the story; it is what is done with them that is the measure of the man."

Annual Report of the International Airport Activated Sludge Plant, Miami, Fla., for 1950

By John S. Whitney, *Superintendent*

This plant, one of three located at Miami's International Airport, provides complete treatment for domestic wastes from its tributary area. Initial construction, completed in 1945, was designed to serve only one aircraft company installation on a basis of 0.06 m.g.d. of domestic wastes averaging 200 p.p.m. B.O.D. Complete treatment was necessitated by reason of the plant's proximity to restaurants, homes, and other nearby structures, as well as the condition of the receiving stream.

Originally the facilities included a lift station, comminution, primary settling, mechanical aeration, and chlorination. Separate sludge digestion is

TABLE I.—Summary of 1950 Operation Data, International Airport Activated Sludge Plant, Miami, Fla.

Item	Average	Item	Average
Equivalent population (B.O.D.)	2,800	Per lb. B.O.D. removed	6.8
Sewage treated (m.g.d.)	0.086	Aeration:	
Raw sludge:		Units used	2
Pumped (g.p.d.)	3,072	Hours per day	43
Total solids (p.p.m.)	800	Susp. sol., centrifuge (p.p.m.)	1,000
Volatile solids (%)	62	Settled (%)	36
pH	6.8	Sludge vol. index	360
Suspended solids, Gooch (p.p.m.):		D.O., aerators (p.p.m.)	1.5
Influent	320	D.O., final effl. (p.p.m.)	3.7
Primary effluent	132	Primary tank:	
Final effluent	9.8	Settl. sol., influent (p.p.m.)	18.3
Total removed (lb./day)	2,660	Settl. sol., effluent (p.p.m.)	4.3
Digested sludge, moisture (%):		Removal (%)	76.7
Maximum	91	pH, influent	7.8
Minimum	83	pH, effluent	7.4
B.O.D. (p.p.m.):		Final effluent:	
Influent	192	B.O.D. (p.p.m.)	3
Primary effluent	136	M.P.N.	324
Final effluent	3	Relative stability (days)	12
Reduction, over-all (%)	97	Receiving stream:	
Total removed (lb./day)	1,500	Flow (c.f.s.)	150
Chlorine:		B.O.D. above outfall (p.p.m.)	9
Used, on effluent (lb./day)	13	D.O. (p.p.m.)	4.0
Residual, 15-min. contact (p.p.m.)	1.15	Operating costs ($):	
Power used (kw.-hr.):		Total for year	12,200.00
Per day	238	Per m.g.	394.00

provided in a fixed cover, unheated digester having a capacity of 9.23 cu. ft. per capita. The receiving stream, located about 3,600 ft. from the plant, has an average dry-weather flow of 150 cu. ft. per sec.

The plant was enlarged in 1949 to 0.2-m.g.d. capacity at 300 p.p.m. B.O.D. This was accomplished by addition of a pre-aeration unit, additional lift stations with comminution, and a second aerator-clarifier unit.

With an attached population of 2,800 (at 45 g.p.c.d.), the plant is running at about two-thirds its rated capacity. Maximum flow of about 0.18 m.g.d. is received for about 12 hr. per day, with the minimum flow, about 0.10 m.g.d., during the remainder. Prior to enlargement the influent was often septic, due to long periods between lift station pump operation at low flows. However, the new units have eliminated this trouble, as well as relieving the plant of all shock loads.

Plant personnel are all certified under the voluntary certification plan in operation in Florida.

Operation data for 1950 are summarized in Table I.

Annual Report of the Dallas, Tex., Sewage Treatment Plant for the Year 1949–50 *

By Ben L. Grimes, *Superintendent*

Plant Overloaded

The existing treatment facilities are greatly overloaded, with approximately 40 m.g.d. being handled in a plant designed to treat an average of 32 m.g.d. During the year, weekday 5-hr. peak rates of flow from 50 to 65 m.g.d. have been experienced. Even with the extreme overloads, however, very good treatment results are being obtained with the existing facilities.

Additions and Repairs

Construction has started on two new grit channels, scheduled for completion by November, 1950. With completion of these units it is planned to take the existing channels out of service for general reconditioning of all equipment.

New fiberglass orifice plates were installed in the 64 distribution arms, resulting in complete coverage of the filters with sewage. Considerable trouble was experienced with blowing of mercury seals in the center columns of the distributors. This condition was corrected by removing from each distributor a plate placed in the center column several years ago to prevent corrosion of the upper section of the column.

Several electrical conduits were dug up and encased in concrete to prevent ground water from entering the conduits and running back to the control boards. In addition, the control boards for the secondary settling tanks and the recirculation building were overhauled and repaired.

The 20-m.g.d. pump was out of service for a short period due to the shaft bearings freezing the shaft and preventing it from turning. After sanding down the neoprene bearings the pump was returned to operation. This was the third time this has happened in the 10 years this pump has been in use.

Both digesters are out of service for inspection, cleaning, and repairs. The primary digester was found to have about 50 cu. yd. of sand, pea gravel, and other heavy material in the bottom; one heating coil had been pulled loose from the floor, and all heat exchanger piping was coated with sludge

* For last previous extract see *Sewage Works Journal*, **19**, 6, 1077 (Nov., 1947).

TABLE II.—Summary of 1949–50 Operating Data, Dallas, Tex., Sewage Treatment Plant

Item	Average
Estimated population served	483,700
Rainfall (in.)	47.22
Raw sewage flow (m.g.d.)	38.2
Screenings (cu. ft./day)	32.2
Grit (cu. ft./day)	127
Settleable solids (ml./l.):	
Raw	9.8
Primary tank effluent	0.2
Imhoff tank effluent	0.3
Filter effluent	1.2
Final tank effluent	0.2
B.O.D. (p.p.m.):	
Raw	316
Primary tank effluent	181
Imhoff tank effluent	196
Filter effluent	47
Final tank effluent	33
Dissolved oxygen (p.p.m.):	
Filter effluent	3.7
Final tank effluent	4.0
Suspended solids (p.p.m.):	
Raw	347
Primary effluent	78
Filter effluent	70
Final effluent	34
Sludge data:	
pH:	
Primary settling tank sludge	6.0
Transfer sludge	6.6
Secondary digester sludge	6.9
Supernatant	6.9
Imhoff tank sludge	5.9
Secondary settling tank sludge	6.6
Dry solids (%):	
Primary settling tank sludge	4.8
Transfer sludge	3.5
Secondary digester sludge	6.0
Supernatant	1.5
Imhoff tank sludge	5.6
Secondary settling tank sludge	2.0
Dry volatile solids (%):	
Primary settling tank sludge	75.0
Transfer sludge	63.4
Secondary digester sludge	55.0
Supernatant	56.8
Imhoff tank sludge	72.4
Secondary settling tank sludge	67.5
Trickling filter data:	
Sewage applied (m.g.a.d.)	5.14
Loading (lb. 5-day B.O.D.):	
Per acre per day	7,610
Per cu. yd. stone	0.63
Per acre-foot	993
Cost of operation ($):	
Total	87,057.22
Per m.g.	6.56

cake from ¼ to ½ in. in thickness. The mixer bearings were badly worn and the seal between the fixed metal roof and the concrete walls was leaking badly. In the secondary digester, 15 of the steel guy rods running from the center column were broken.

Chlorination

The two chlorine machines, which have not been in use for some time, have been returned to the factory for conversion to fully automatic machines and for increasing their capacity from 2,000 to 2,500 lb. per day each. These machines are to be installed in the distribution well house so that chlorine can be applied at the influent end of the secondary settling tanks and to the plant effluent before it is discharged to the Trinity River.

Operating data for 1949–50 are summarized in Table II.

1950 Annual Report of Portsmouth, Va., Sewage Treatment Plant

By B. F. Rockecharlie, *Plant Manager*

Plant Description and History

The plant was put into operation on May 2, 1949, as a result of the Hampton Roads oyster grounds being condemned because of pollution. Questionable quality of adjacent bathing waters in this resort area also played a large part in providing impetus to the pollution abatement program of the communities in the area.

Sewage from the estimated tributary population of 90,000 in the city and adjacent county areas is chlorinated before passing through mechanically raked bar screens (¾-in. open-

ings) and a grit chamber prior to receiving primary treatment in straight-line sedimentation tanks. Separate sludge digestion is provided by one fixed cover digester and one floating cover digester, each of 375,000-gal. capacity, designed for either parallel single-stage operation or as a two-stage system in series. The latter method is employed at present. Digested sludge is elutriated, dosed with ferric chloride, and dewatered on two 150-sq. ft. vacuum filters. Dried sludge cake is utilized by the city on public grounds.

Personnel

The 13-man operating force consists of a plant manager, a chemist, a maintenance man, a maintenance helper, a chief operator, four shift operators, and four shift helpers.

General Activities

From the beginning, the reputation of the plant has suffered because of the poor quality of the influent. Flat grades and consequent low velocities set up ideal conditions for decomposition of the raw sewage in the collection system. Because obnoxious odors cannot be vented to the atmosphere from the force mains leading from the five pumping stations, they are all concentrated at the treatment plant. The obvious solution is to keep the sewage from decomposing until it reaches the plant. Therefore, during the summer of 1950 chlorinators were installed at three of the pumping stations. However, the required chlorine dosage was considerably higher than had been anticipated, probably due to the onset of hot weather before the installations were completed.

During the year the State Board of Health desired considerably more bacteriological data than was originally expected. This problem results from the proximity of the important shellfish grounds in the receiving waters. To facilitate running the additional tests, the laboratory was expanded so that bacteriological examinations of the sewage are now run at the plant instead of at the Public Health Department.

After almost two years of operation, the only major repairs required have been normal general overhauling of the gas engines.

Sources of Revenue

Revenue is derived from a sewer service charge based on water consumption. Bills are sent either quarterly or monthly, the rate being the same under both methods of billing.

TABLE III.—Summary of 1950 Operation Data, Portsmouth, Va., Sewage Treatment Plant

Item	Average	Item	Average
Estimated population served	90,000	Raw sludge:	
Sewage flow (m.g.d.)	7	To digester (lb. dry sol.)	8,125
Screenings (cu. ft./day)	10	pH	5.6
Grit (cu. ft./day)	1	Volatile solids (%)	75
Suspended solids:		Digested sludge:	
Influent (p.p.m.)	192	To filter (lb. dry sol.)	2,300
Effluent (p.p.m.)	75	Ferric chloride dosage (%)	3.0
Reduction (%)	61.0	Gas production (cu. ft.):	
Settleable solids:		To boiler	7,000
Influent (ml./l.)	5.8	To engines	36,000
Effluent (ml./l.)	0.2	To waste	21,000
Reduction (%)	96.7	Total	64,000
B.O.D., 5-day:		Power production (kw.-hr.):	
Influent (p.p.m.)	250	Used in plant	510
Effluent (p.p.m.)	170	Sold to local utility	770
Reduction (%)	32	Total generated	1,280

On a monthly basis, the following schedule applies:

Up to 400 cu. ft.	(min.)	$0.50
Additional to 3,000 cu. ft.		$0.10 per 100
Additional to 33,000 cu. ft.		$0.085 per 100
Additional to 333,000 cu. ft.		$0.07 per 100

Negotiations are almost complete whereby the city will purchase Hampton Roads Sanitary District Commission facilities lying within the corporate limits. This transaction will reflect favorably on future revenue.

The sale of excess power to the local electric utility was begun in April, 1950. During the remaining eight months of the year the power company paid the city approximately $2,500 for power.

Operation data for 1950 are summarized in Table III.

Annual Report of the Sewage Treatment Plant, Danville (Ill.) Sanitary District for the Year 1950

By J. E. Meers, *Chemist*

Description of Plant

The Danville, Ill., Sanitary District sewage treatment plant, first put into operation in February, 1937, provides primary treatment consisting of rotary mechanical screening, comminution, de-gritting, flocculation, and settling. Facilities are available for enhancing flocculation by the addition of chemicals. Separate sludge digestion is accomplished in a floating cover digester of 75,000 cu. ft., with a similar unit serving as a sludge storage tank. Digested sludge is dried on 12 open beds totaling 40,000 sq. ft.

Plant Flooded

On January 3, 1950, the plant was flooded out by a sudden rise of the Vermillion River, to which the plant effluent discharges. The likelihood of this happening had been foreseen some years ago, at which time a levee was constructed around the plant. Although the river rose to 1.5 ft. above the levee, the additional time afforded before the levee was overtopped allowed arrangements to be made for dismantling and removing motors, etc. As a result, damage was held to a minimum, repair costs were negligible, and the plant lost only seven days of operation.

Personnel

Adjustments made in plant employees' wages this year bring them closer to the level of other municipal employees performing work of a similar nature. Beginning with January 1, 1951, the District will become a member of the Illinois Municipal Retirement Fund, thus giving the employees more adequate protection for accidents and retirement.

TABLE IV.—Summary of 1950 Operation Data, Danville, Ill., Sewage Treatment Plant

Item	Average	Item	Average
Rainfall (in.)	48.25	Final effluent	82
Estimated population served	35,000	Raw sludge:	
Sewage flow (m.g.d.)	4.723	To digester (gal.)	14,800
Grit (cu. ft./day)	1.95	Solids (%)	4.7
Settleable solids (ml./l.):		Volatile solids (%)	68.6
Raw	6.1	Gas production (cu. ft./day)	26,400
Final effluent	0.6	Dig. sludge to drying beds (gal.)	830,900
Suspended solids (p.p.m.):		Cost of operation ($):	
Raw	183	Total	38,763.99
Final effluent	72	Per m.g.	22.46
B.O.D. (p.p.m.):		Per capita	0.905
Raw	211		

So far the District has a fine record regarding accidents. The year 1950 was no exception, with no lost-time accidents being recorded.

Gas Production

For the first time since the plant started operations the digested gas supply had to be supplemented. This was because of the high river stages in January, which either flooded out the plant or necessitated by-passing the flow for 11 days. Also, an entire month's gas production was lost during July while the digester was being cleaned. To avoid any future possibility of low digester temperatures because of low gas supply, a burner has been placed in the boiler to burn either oil, or gas, or both.

Table IV gives a summary of 1950 operation data.

TIPS AND QUIPS

Sewage Pumping Tips

Some valuable hints on getting the most out of sewage pumping stations are contained in a paper on "Fundamentals of Sewage Pumping," by Glenn E. Hands, appearing elsewhere in this issue. Of particular interest to operators is the last section of the paper, in which Mr. Hands passes on some suggestions on improving pumping station performance and reducing power costs.

A Lot of Fish

One person would have to eat, at a single sitting, 100 lb. of Columbia River salmon caught just below the Hanford atomic energy works at Richland, Wash., to take into his body a noticeable amount of radioactive material resulting from operation of these works. This shows how slightly such operations affect the nearby area, including the Columbia River, according to officials of the operating company, who point out that water used in the plant is returned to the river only after its radioactivity has been reduced to the vanishing point.

Bring Your "Who's Who" Up to Date

In the critical period ahead there will be enough unavoidable delay by factors beyond your control to make procurement of emergency repair parts a major headache without putting in your path any self-imposed obstacles. Therefore, it behooves each person responsible for plant maintenance or repair to make sure that his file of "who and where," particularly with respect to items that may be out of stock or difficult to secure on short notice, is brought up to date as soon as possible.

Many times a request for parts or help is addressed to someone who has long since left a company, or to the wrong department of a company, only because that is the last name or address appearing in the plant files. In either case, delay ensues in locating the correct person to handle the matter. This situation is particularly liable to arise where the original manufacturer has gone out of business or has been absorbed by another company, or where the original purchase or contact was made through some sales or service representative, perhaps several years ago.

NOW is the time to check up and see that your file of who-to-see-about-what is as nearly up to date as you can get it.

In Quadruplicate?

The Pentagon, U. S. Army headquarters at Arlington, Va., has been

reported to have cost about $65,000,000. However, because it brought together Army personnel from 17 different buildings, mostly rented, the rental savings alone are said to have paid for the vast building.

But the savings are not confined to rental charges alone; it is also reported that enough return is realized from the waste paper collected in the building to pay the salaries of several of the leading officials having offices there. Maybe that's where all those extra copies of government forms go!

Odor Control in Tannery Waste Settling Ponds

Handling 750,000 g.p.d. of waste containing heavy chemicals and putrescing hide remnants, the two large settling ponds comprising the treatment plant at the Bolivar, Tenn., tannery of the International Shoe Company presented a serious sulfide odor problem. Each of the ponds is an earthen basin 500 ft. by 400 ft. by 4 ft. deep, maintained at an optimal 18-in. operational depth. Alternate use of the ponds at two-week intervals enhances the settling and aeration functions of the basins. The waste is led to the ponds by open concrete channels of sufficient grade to provide self-scouring velocities.

This latter feature is utilized as a ready means of eliminating the sulfide odors. Dumping two barrels of anhydrous ferric sulfate into the main channels each day has reduced the atmospheric hydrogen sulfide in the lagoon area to well under 0.5 p.p.m. This effect results from the precipitation of the sulfides in the waste as iron sulfide in the alkaline pond waters (pH 7.8 to 8.0). In addition, the coagulating effect of the iron salt completely removes the settleable solids as the waste is treated in the pond. Adequate mixing of the chemical is achieved solely through the turbulence of the flow in the open influent channels.

Powerful Stuff

In an effort to reduce the contaminating effect of waste metal plating solutions to language understandable to platers, the Metal-Finishing Industry Action Committee of the Ohio River Valley Water Sanitation Commission translates the stream pollution problem with the following example:

> Suppose a 100-gal. tank of cyanide solution is to be dumped. Strength of the solution is only 5 oz. of cyanide per gallon—a weak solution in terms of plating. The plant is located in a state where the permissible limit for cyanide is 0.10 p.p.m. Inasmuch as 1 oz. of cyanide per gallon is equivalent to 7,500 p.p.m., to reduce the concentration of the 100 gal. of waste to the permissible limit by dilution will require 37,500,000 gal., or enough water to cover a football field to a depth of 105 ft.

Or, we might add, that's enough cyanide, or water, or both, to give any treatment plant operator reason to shed an equal volume of blood, sweat, and tears!

Sulfur from Waste Gases

Sulfur, now in short supply because of current defense efforts, is being recovered from waste gases in large quantities, according to a paper presented by B. W. Gamson and R. H. Elkins at the recent Kansas City meeting of the American Institute of Chemical Engineers. Hydrogen sulfide, the primary gas involved, is a by-product of several industrial processes.

Purification of coal gas used as heating fuel was the original application of the sulfur recovery process. However, natural gas and petroleum are now supplanting coal as the principal source of waste hydrogen sulfide. The advent of the catalytic cracking process and the increased use of high-sulfur crude oils have greatly expanded the interest of the petroleum industry in the process, according to the authors, who reviewed and com-

pared the known methods of sulfur recovery.

We'll bet that some sewage and industrial waste treatment plant operators would like to convert their excess H_2S to a useable by-product, if only in the interests of corrosion and odor control!

Modernistic Hazard

Before eye-catching stripes could be painted on the clear glass doors of a new building in Seattle, Wash., a man collided with one of the big panes and received some very real pains—in the shape of a bruised nose, two black eyes, and a broken tooth. In filing a $10,000 claim against the city, owner of the building, he felt that insult had been added to the injury because he found that the "accident" occurred at the new Public Safety Building!

If you're planning on using any "invisible" doors around your plant, better make sure they are equipped to catch the user's eye before he tries to walk through without opening them.

Small Details Caused Big Trouble

Details of a gas explosion at the Greeneville, Tenn., sewage treatment plant some two years ago were given in a discussion of digestion practices presented at the 1950 Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association by J. W. McAmis, superintendent. The trouble began when excessive scum in the heated, fixed cover digester rose into the gas dome and filled the gas line leading to the control house, as well as all the meters, regulators, flame traps, etc., connected with the heating units for both the digester and the plant buildings. This necessitated dismantling and washing out all the piping and the appliances.

The job seemed to be progressing nicely, but the operator had forgotten two small details. First, he had neglected to remove the manhole cover on the gas dome and allow the trapped gas to escape to the open air. As the gas line was opened, gas flowed into the control house. Eventually, the gas-air mixture reached explosive proportions.

The operator was fully aware of the hazards of open flames under these conditions. Being a non-smoker, his major concern was to prevent sparking by tools. However, he overlooked a small electric heater, previously turned on because of the cold. When the gas-air mixture contacted the red-hot heating element, the resulting explosion lifted the control house roof, blew out all the windows, and burned the operator so badly that he was hospitalized for about a month.

Moral—Where sludge gas is involved, safety precautions must take first priority!

Making Crime Pay

When competitive bids were received for construction of a new sewage disposal plant at the London, Ohio, prison farm, the lowest was more than $240,000, including $100,000 for labor. However, the state is saving the $100,000 labor costs on the project by assigning 19 prisoners to construction tasks.

We wonder if they have any experienced help—among the inmates, that is—to run the new plant when it's finished.

Plant on Sliding Scale

When a recent inspection by the Washington State Pollution Control Commission revealed that the Val-Vue Sewer District sewage treatment plant was in imminent danger of sliding downhill, the Commission held a meeting with the District commissioners and engineer to discuss the problem of sewage treatment. According to the Commission's "Progress Report No. 27," covering the four months ending March 31, 1951, the slide problem is

apparent to everyone and probably could be corrected by the expenditure of some money.

However, the plant is too small at present and several additional areas are desirous of connecting to the system. Plans are to be made for construction of a new plant and annexation of additional areas above the present district and along the route of the new main trunk to the plant site.

To paraphrase a recent famous quotation, "Old plants never die; they just slide away"—to be replaced by newer and more efficient treatment units!

NPA WATER RESOURCES DIVISION

Creation of a Water Resources Division within the National Production Authority was officially announced on July 18, 1951. Prior notice of the Division's inception had already been given unofficially (see THIS JOURNAL, **23**, 6, 738; June, 1951).

Responsibility of the Water Resources Division will include (1) ground and surface water supply, transmission, pumping, treatment, storage and distribution for domestic and industrial use, and (2) liquid wastes and sewage collection, pumping, treatment and disposal, whether from domestic or industrial sources.

The Division is to prepare programs to assure an adequate supply of water and sewage services to support defense and essential civilian activities. In this connection it will distribute allotments of materials, supplies and equipment required for the programs, recommend the issuance of priorities necessary to carry out the programs, and act in cases where special "spot" assistance is required.

The Division is headed by Harvey S. Howe, who is on loan from the Lock Joint Pipe Co., East Orange, N. J. His assistant will be James C. Crenshaw, who is on loan from the American Water Works Co., which he served as division engineer at Richmond, Ind.

A field staff will not be recruited for the Division, according to Mr. Howe. Instead, the Division will draw upon the U. S. Geological Survey, U. S. Public Health Service, Housing and Home Finance Agency, and state and local sanitary engineers for information available in those agencies.

The Water Resources Division may have to take positive action in attacking pollution of national water resources, explained Mr. Howe, as less critical material is needed to treat wastes at their source than to reclaim the water into which they are dumped. Thus, to provide for downstream water requirements of defense plants and supporting communities, the Division may need to insist in some instances on the building of sewage and waste treatment facilities.

Normally, priority matters are to be handled through the nearest Department of Commerce field office now acting for NPA. Where special cases are involved, in sewage and wastes works, communications may be addressed to Water Resources Division, National Production Authority, U. S. Dept. of Commerce, Washington 25, D. C.

Federation Affairs

ST. PAUL MEETING PROGRAM TAKES SHAPE

Arrangements for the Twenty-Fourth Annual Meeting of the Federation of Sewage and Industrial Wastes Associations, to be held at St. Paul, Minn., on October 8-11, 1951, are already virtually complete. Advance indications are for a large registration and an eminently successful technical and social program designed to suit the maximum number of the Federation's diversely interested members. The Central States Sewage and Industrial Wastes Association is acting as host to the Federation at the St. Paul meeting.

Local Arrangements Committee

The membership of the Local Arrangements Committee, which has already completed many of the final details, comprises the following sub-committee chairmen:

General Chairman: Kerwin L. Mick, superintendent and chief engineer, Minneapolis-St. Paul Sanitary District.

Hotel Arrangements: Maurice L. Robins, chemist, and Louis J. Bartscher, executive secretary, Minneapolis-St. Paul Sanitary District.

Registration: Arndt J. Duvall, sanitary engineer, Tolz, King & Day, Inc., St. Paul.

Finance: Harvey G. Rogers, director, Division of Water Pollution Control, Minnesota State Board of Health, Minneapolis.

Inspection Trip: B. M. Storey, operator, Minneapolis-St. Paul Sanitary District.

Local Host: George J. Schroepfer, professor of sanitary engineering, University of Minnesota.

Entertainment: Willard Bell, district manager, Wallace & Tiernan Co., Inc., Minneapolis, and Dean E. Colvin, field engineer, Infilco Inc., Minneapolis.

Ladies' Entertainment: Mrs. George J. Schroepfer and Mrs. Kerwin L. Mick.

Location of Activities

Most of the convention's technical activities will be centered around the St. Paul Municipal Auditorium, where all but the Thursday morning forums and the Wednesday afternoon inspection trip will be held. The Auditorium also will be the locale for the Manufacturers' Exhibit throughout the meeting, as well as for the Monday evening Entertainment.

Functions of the meeting to be held in places other than the Auditorium include the Annual Federation Luncheon and the Central States Smorgasbord on Tuesday, and the Annual Banquet and Dance on Wednesday evening. The first is scheduled for the Hotel Lowry, the last two for the St. Paul Hotel.

Hotel Accommodations

Those planning to attend the meeting are urged to make hotel reservations without delay. Block reservations of accommodations have been arranged at the Hotel Lowry, the St. Paul Hotel, and the St. Francis Hotel, to be assigned to attending members on a first-come-first-served basis. Requests for reservations should be directed to one of the hotels, not to Federation headquarters.

Technical Program

In keeping with the expanded activities of the Federation, the technical program shows comprehensive topical coverage and diversity sufficient to interest individuals specializing in all fields. Members will have received pre-convention announcements of the complete program by the time this is published. Attention is called, however, to the varied and timely papers in the areas of sewage treatment, industrial wastes treatment, and stream pollution.

The highlight of the technical program is expected to be a review of the materials situation by Harvey S. Howe, chief of the newly established Water Resources Division, National Production Authority. As head of the claimant agency for waste treatment works procurement, Mr. Howe will have up-to-the-minute answers on the regulations governing these activities.

For the third year, the highly acclaimed "Industrial Wastes Forum" will share the Thursday morning spotlight with the perennially popular "Operators' Forum." Running concurrently, these two sessions will offer discussion of practical problems in their respective fields. The "Industrial Wastes Forum" will be presided over by Clair N. Sawyer, of Massachusetts Institute of Technology; the "Operators' Forum" will be under the leadership of George E. ("Doc") Symons, managing editor of *Water and Sewage Works*.

Other sewage works papers will deal with filter fly control, concentration of raw sludge, high-rate chemical and biological treatment of sewage, the activated sludge process, operations of the Winnipeg (Canada) Sanitary District, record keeping for sewer systems, and the use of instruments in sewage treatment.

Stream pollution papers will deal with principles of stream classification for best usage, pollution abatement activities in New Jersey, and the relationship of air pollution to water pollution.

The Wednesday morning session will be devoted to such specific industrial waste disposal problems as plating wastes, chlorination of phenolic wastes, and the determination of equitable sewer charges for industrial wastes.

A full afternoon will be devoted to an inspection trip of the extremely interesting Minneapolis-St. Paul Sanitary District plant and the South St. Paul sewage treatment plant.

The speaker at the Annual Federation Luncheon on Tuesday noon, October 9, will be an outstanding personality in the water pollution control field.

Social Program

Included in the social events of the convention will be a Mixer and Entertainment on Monday evening, October 8; the Annual Dinner and Dance on Wednesday evening, October 10; and a full schedule of special events for the ladies. In addition, the host Central States Sewage and Industrial Wastes Association will hold a Smorgasbord in connection with its Business Meeting on Tuesday evening, October 9.

Ladies' Special Events

In addition to the events already mentioned under the heading "Social Program," the Ladies' Entertainment Committee has planned a get-acquainted tea, compliments of the Central States Sewage and Industrial Wastes Association; a tour of the Twin Cities and scenic surroundings, with luncheon at the Sibley Tea House; and a tour of the Betty Crocker Kitchen, famous research kitchen of General Mills, Inc., followed by a Dutch treat luncheon in the Dayton Department Store Sky Room, overlooking downtown Minneapolis.

Manufacturers' Exhibit

Member companies of the Water and Sewage Works Manufacturers' Association are indicating intense interest in the annual equipment display. The exhibit will be in spacious Stemm Hall, part of the Auditorium facilities. An unusually interesting and diversified showing of equipment and supplies in the several areas of sanitation work is expected.

Early Registration

To help early arrivals at the convention avoid the usual last-minute registration rush on Monday morning, it has been arranged to have the registration desk open at the Auditorium from 2 P.M. to 5 P.M. on Sunday, October 7. Pre-registration is urged for all those in town during this period.

Announcement to Membership

All Active and Corporate Members of the constituent associations of the Federation have been sent a formal announcement of the convention. Contained therein are further details of value to those planning to attend. Early reservation of hotel accommodations is particularly urged, and should be placed directly with the hotel concerned. When requesting reservations mention should be made that the accommodations are sought for the Federation convention.

Reviews and Abstracts*

Behavior and Distribution of the Larger Worms in Trickling Filters. By R. J. Terry. *Water and Sanit. Eng.*, 1, 12, 432 (1951).

Two types of earthworms were found in the filters studied; namely, *Lumbricus rubellus* and *Eisenia foetida*. Both species measure about 10 cm. in length when mature. The former produces 90 offsprings per year; the latter, 11. In trickling filters earthworms are not active on the surface of the bed, but are found in great numbers in the humus tanks. They are most abundant in beds of smaller-sized media. At one plant with small-sized media 700 earthworms were obtained per cubic yard of media. Worms are more abundant in the surface of the filters in autumn and fall than in spring and summer. They show an aversion to light and migrate nocturnally to the surface of the bed. Results from laboratory experimental filters showed that the filter artificially colonized with earthworms gave a higher efficiency of purification than the control. The author does not consider leeches of importance in the trickling filters.

Increase in population of earthworms in filters is slow, but once the population has been built up it will remain relatively stable because of their greater power of movement, which enables them to retreat quickly under adverse conditions. The seasonal variation of the worms in filters is attributed to the effect of the grazing activities of other members of the filter fauna in the bed. The activity of insect larvae in the spring decreases the quantity of film, both by direct feeding and by loosening of the growths, resulting in sloughing. It leaves the worms with insufficient food and as a result they migrate to the lower depths of the bed. In autumn, as the film builds up again, the worms return to the surface. The earthworms perform a valuable role in the scouring filters having small-sized media, even though they do not occur in numbers comparable to other members of filter fauna. It was estimated that the worms found in the filter could deal with 3 cu. ft. of film per week. It is concluded that earthworms, in spite of the nuisance they cause in the humus tanks, are valuable members of the grazing fauna, especially in filters with small-sized media. Their value is increased because they are most active at times when the grazing activities of the insect larvae are much reduced. To avoid the long period required for the colonization of a new filter, the filter could be inoculated with worms obtained from another plant.

H. Heukelekian

Treatment of Sewage and Industrial Waste Waters. *Surveyor*, **109**, 588 (Nov. 17, 1950).

The work of the Water Pollution Research Laboratory during 1949 is described in "Water Pollution Research, 1949", recently published. Sewage treatment by biological filtration has been under investigation by the Laboratory for some years. There have been indications that if the rate of application of settled sewage is increased sufficiently the tendency to pond on the surface is reduced.

Rates of application ranging from 100 to 1,000 gal. (Imp.) per cu. yd. of medium per day have been used, and it is planned to use even higher rates. The quality of the effluent deteriorates as the rate is increased, but the efficiency (expressed as the quantity of oxidizable matter removed

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and education institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

per cubic yard of media) increases linearly with the rate of application.

Investigations also were carried on with the removal of humus from filter effluents by means of pressure filters, open gravity filters, and treatment by microstraining. Treatment in the open gravity filters reduced the oxygen demand by 60 to 75 per cent.

Work is described on the treatment of wastes from the manufacture of paper, mainly from rag and hemp. The waste waters were usually so alkaline that neutralization with carbon dioxide was necessary before biological treatment. Compounds of chlorine with organic substances were removed with the use of ferrous sulfate, excess of which was oxidized by use of air.

T. L. HERRICK

Disposal of Sewage Sludge by Composting with Household Refuse: The Economic Aspect. By W. P. WARLOW. *Surveyor*, **109**, 599 (Nov. 24, 1950).

The London County Council has been conducting experiments on the composting of sewage sludge and sewage screenings with ground household refuse. For more than 50 years the sludge produced has been barged to sea for disposal. Disposal of household refuse is a function of the Metropolitan Borough Councils. The County Council was concerned, apart from the desire to return sewage solids to the land, in investigating a method of disposal as an alternate to disposal at sea.

It has been decided to abandon the production of sludge-refuse compost and to continue the making of screenings-refuse material. The refuse is now of very poor quality organically and it is uncertain whether the continued use of a highly mineralized compost would be satisfactory agriculturally. The location of the outfalls is not favorable as regards transportation costs. If the demand for compost should be inadequate, disposal of sludge might be very difficult if the present sludge vessels were not replaced.

T. L. HERRICK

Pollution of the Charles River. By M. P. HORWOOD, J. D. FRAME, AND R. E. MCKINNEY. *Jour.*, Boston Soc. Civil Eng., **37**, 170 (Apr., 1950).

This is the report of a group from Massachusetts Institute of Technology on a spring survey intended to show the magnitude and scope of the pollution of the Charles River. The survey was conducted at weekly intervals for three months, February, 1949, through April, 1949, and covered 32 sampling points. Both chemical and bacteriological tests were made on samples taken. D.O. and oxygen saturation were found to be the best indicators of recent pollution from wastes and the M.P.N. the best means of determining the amount of fecal pollution.

The report concludes that the Charles River is being polluted largely by domestic sewage and that the pollution present in the Basin poses a definite threat to the health of people using the bathing beaches in this area.

GEORGE T. BRYANT

The Design and Construction of the Treatment Plant for Wool Scouring and Dyeing Wastes at Manufacturing Plant, Glasgow, Virginia. By L. W. RYDER. *Jour.*, Boston Soc. Civil Eng., **37**, 183 (Apr., 1950).

This is a presentation of the design and the results of a plant treating 73,000 g.p.d. of alkaline and greasy scouring wastes and 177,000 g.p.d. of acid dye-house waste. The alkaline waste is neutralized with the acid waste. More acid (sulfuric) must be added to the waste to crack the grease. This is followed by utilizing the lime sludge of the water treatment plant to neutralize the acidified waste.

GEORGE T. BRYANT

The Quality of Storm Weather Flow. By GUNNAR AKERLINDH. *Satryck ur Nordisk Hygienisk Tidskreff*, **31**, 1 (1950).

The quality of storm-water flow, particularly the surplus discharge from combined sewers, is discussed in order to compute the required regulated flow; that is, the amount of flow to be diverted for disposal. The three elements constituting storm-weather flow—namely sewage, ground water, and rain water, have been considered. Coliform bacteria in samples taken from streets (high runoff coefficients) and parks (low runoff coefficients) were compared. The concentration of organic matter in rain-water flow is comparatively great (B.O.D. 100 to 200 p.p.m.), being nearly as polluted as sewage. In regard to coliform organisms, however, the rain-

water portion of the storm-weather flow has a density of 100 to 1,000 per ml. and, accordingly, is much lower than sewage and has a diluting effect on the sewage. The composition of rain-water flow varies greatly and indefinitely. Despite this, it is reasonable to assume a constant composition.

H. HEUKELEKIAN

Proportionality in Water Pollution. By GUNNAR AKERLINDH. *Acta Limnologica* (Sweden), No. 2 (1949).

To obtain some confirmation of the hypothes s that there is a proportionality between bacterial pollution entering a stream and the resulting bacterial density at continuous pollution, a number of laboratory experiments were run with continuous additions of pollution and with only an initial addition of pollution. The water used in these experiments was an unpolluted surface water. Various volumes of sewage (strained and settled) were repeatedly (at daily or twice daily intervals) added to the water. The coliform density was determined by counting typical colonies on Congo-red agar after 24-hr. incubation at 37°C. It is stated that the results obtained by this method agree closely with those obtained by the lactose fermentation method.

The results show that with only a single dosage of pollution there was a proportionality between the added number of bacteria and the residual bacterial density remaining after various periods of incubation up to 72 hr. Similar results were obtained from continuous feeding experiments.

H. HEUKELEKIAN

Required Regulated Flow. By GUNNAR AKERLINDH. *Acta Polytechnica* (Sweden), No. 58 (1950).

The author presents a method of calculation of required regulated flow; that is, the necessary amount of storm-weather flow in a combined sewer to be diverted for disposal. It takes into account those quantities of sewage, rain water, and stream runoff which determine the resulting stream pollution due to surplus storm-weather flow discharge. Duration (distribution) curves are set up, on the basis of which the resulting initial stream pollution can be determined with the help of probability calculus. With varying values of regulated flow, a series of such duration curves will be obtained. A value is then selected for the regulated flow so that the water pollution due to surplus discharge is considered permissible in both biological and hygienic aspects. Due regard is taken of the self-purification capacity of the stream. A simplified and somewhat less accurate procedure is also presented, by means of which extensive probability calculations are carried out only once for a given climate. The method of calculation ought to furnish a satisfactory estimation of required regulated flow and furnish data for the proper size of the intercepting sewers. Setting up of the duration curve for resulting stream pollution due to surplus discharge offers a view of actually prevailing conditions of pollution.

H. HEUKELEKIAN

Radioactive Waste Disposal—A Bibliography of Unclassified Literature. By ROBERT L. SHANNON. U. S. AEC, TID-375. Price 10¢ (Aug., 1950).

Forty nine annotated abstracts of unclassified literature have been compiled. These abstracts pertain to the following subjects: waste disposal, 23; solid waste disposal, 2; rules and procedures for handling radioactive wastes, 10; problems arising from the use of radioactive isotopes in the medical field, 5; the disposal of radioactive gases, 7; and the design of laboratories for handling wastes, 2.

L. R. SETTER

Atomic Energy and the Physical Science. U. S. AEC. Available from U. S. Gov. Printing Off., Washington, D. C. Price 50¢ (1950).

The activities and development in the atomic energy program during 1949 are contained in a 221-page document outlining the activities and research studies underway. The estimated cost of the activities for the fiscal year 1950 is $698,000,000. Some 3,500 scientists are conducting research on the physical, biological, and medical sciences at an estimated cost of $48,000,000. The number of radioactive isotopes shipped to states and counties numbered 9,612 as of December 31, 1949.

L. R. SETTER

Modernization of Sewage Treatment Plant, Cordoba, Argentina. By Hector Julio Isernia. *Obras Sanit. de la Nacion*, No. 137, 81 (Oct.-Dec., 1950).

The city of Cordoba enjoys the most modern treatment plant yet constructed by the national sanitary works section. A plant for treating sewage from 125,000 people has been completed as part of the over-all program to care for the 250,000 future population load. Sewage reaches the plant by gravity, passes through a mechanical bar screen, and flows through primary settling basins with mechanical sludge removal equipment. It then passes on to 8 sand filters, from which collector drains discharge the effluent to the Primero River.

Sludge from the primary settling tank is pumped to the two-stage heated sludge digestion tanks. Gas is collected in the second tank and utilized for driving an electric generator to produce power needed around the plant. Digested sludge is dried on sludge beds and used for fill or fertilizer.

The new plant has been architecturally treated to assure that it will properly fit into the rapidly building area, as "another industrial installation."

L. D. Hudson

Report on the 1949 Program of Metering, Sampling, and Analysis of Sewage and Industrial Wastes, San Jose, Calif. By C. G. Hyde and G. L. Sullivan. 122 pp. mimeo. (June, 1950).

This report presents the problems of the industrial wastes in the San Jose area, which has a large fruit and vegetable processing industry. The 1949 studies were made to bring up to date earlier investigations (1945 and 1946) in the design of sewage treatment works for the area. The measurement of flow and characteristics of the combined domestic sewage and industrial waste are detailed. The seasonal wastes of the industry affect both the volume and character of the sewage. Peak waste production occurs in August, September, and October. When food processing was at a minimum, in June, the sewage contained 510 p.p.m. of B.O.D. and 330 p.p.m. of suspended solids. During the canning period, the monthly averages ranged from 450 to 1120 p.p.m. for B.O.D. and from 320 to 570 p.p.m. for suspended solids. The B.O.D. is exerted more rapidly than for normal domestic sewage.

There are also a number of non-seasonal wastes, which contain per day about 20,000 lb. of B.O.D. and 8,000 lb. of suspended solids. About 400,000 tons of fruit and vegetables are processed yearly, of which peaches, pears, and tomatoes comprise 80 per cent.

In the measurement of sewer flow, the sewer was calibrated by a salt-velocity method and checked by a chemical dilution method, using magnesium chloride. Special studies were made on the wastes from a process producing monosodium glutamate from sugar beet wastes and also from a molasses distillery plant.

Some experimental work was done on the combined sewage and wastes to determine the value of pre-chlorination and pre-aeration in prevention of scum formation. Apparently, excessive quantities of chlorine would be required to prevent scum formation in the sedimentation tanks. Pre-aeration for 20 to 30 min. caused the suspended matter to settle as sludge for 3 or 4 hr. However, aeration for 60 min. was necessary to obtain an oxidation-reduction potential which does not decline during subsequent sedimentation. The period of aeration chosen for design was 1 hr., with an air input of 0.15 cu. ft. per gallon.

The report should interest those concerned with the industrial wastes from fruit and vegetable processing.

Langdon Pearse

Special Report of the Massachusetts Department of Public Health Relative to an Investigation and Study of the Disposal of Sewage and Industrial Wastes in the Housatonic River Valley in the Towns of Hinsdale, Dalton, Stockbridge, Great Barrington, Sheffield, and Lenox, and the City of Pittsfield. (Dec. 1, 1949).

A study was made of the sanitary condition of the Housatonic River in Western Massachusetts, the sources of pollution, the degree of treatment required for sewage and industrial wastes to maintain the river in a suitable condition for the uses intended, and the most reasonably available method of obtaining such treatment.

At the Massachusetts-Connecticut state line, the river has a drainage area of 532 sq. mi., which contains (as of 1945) some 17 towns with a resident population of 82,000. The river flow on 280 sq. mi. thereof averages 1.664 c.f.s. per sq. mi., with a minimum monthly average of 81 c.f.s., or about 0.289 c.f.s. per sq. mi. The maximum flow (Jan. 1, 1949) was 12,800 c.f.s., or 45.7 c.f.s. per sq. mi. The flow is influenced by releases from industrial mill ponds. Except in the vicinity of Pittsfield and the communities along the Housatonic River, the drainage area is sparsely populated.

The discharge of industrial wastes is a major factor in the pollution of the river, contributing about 90 per cent of the organic load, with a volume of 7.58 m.g.d., chiefly from paper and textile industries Certain portions of the river are grossly polluted, particularly within the city of Pittsfield.

The Department recommends that the towns of Hinsdale, Lee, Great Barrington, and Dalton provide suitable treatment works (at least primary treatment plus chlorination) and that Pittsfield provide additional facilities for treatment.

Appended is a report of the consulting engineers, Camp, Dresser & McKee, on the needs of Pittsfield and Dalton. The Pittsfield sewer system is constructed on the separate plan. The sewage is treated by two comminutors and three covered primary settling tanks, each 30 by 200 ft. in plan, 7 ft. deep, followed by an intermittent sand filter (42.3 acres) built in 1902, and also two trickling filters (total area 1.25 acres) 10 ft. deep, followed by two radial-flow settling tanks (55-ft. diameter by 7 ft. deep). The trickling filter influent passes through a revolving screen, drum type, with 3/16-in. openings. About 4.5 m.g.d. is applied to the trickling filters and the balance of around 2 m.g.d. is applied to the sand beds on some 14.55 acres. The remaining sand bed area of 27.75 acres is used for sludge drying, at a loading around 19 sq. ft. per capita.

The entire Pittsfield plant capacity is exceeded, so that at times raw sewage is diverted to the river. The principal industrial waste entering the Pittsfield sewer system is from a tannery. The dissolved oxygen content of the river below the Pittsfield treatment works is very low (ranging from 0.1 to 2.7 p.p.m.), with a 5-day B.O.D. ranging from 2.2 to 7.1 p.p.m.

The consulting engineers recommend a standard for the river of a limiting coliform count (M.P.N.) of 2,300 per ml. of sample, thus requiring chlorination of effluent, and a dissolved oxygen content of not less than 5 p.p.m., such standards to be applied to drought flows, which are exceeded 99 per cent of the time on working days. Further, they recommend enlarging the Pittsfield sewage treatment plant to handle the sewage and industrial wastes from Dalton and the industrial wastes from Pittsfield. A study of oxygen balance in the river indicates that a B.O.D. removal from 88 to 91 per cent is required.

The total estimated construction cost of all improvements in the valley is $2,945,800, of which $1,275,700 is for Pittsfield; $1,143,800 for Dalton; and $526,300 for Pittsfield industries.

LANGDON PEARSE

Diffused Air Floats Particles for Waste Disposal. BY ALLEN I. BARRY. *Chem. Eng.*, **58**, 107 (Apr., 1951).

One approach to suspended solids removal from industrial wastes is to float the solids by attachment of air bubbles to the particles. Successful bubble flotation depends on the availability of air bubbles with a maximum diameter of 0.001 in. or less. A suitable flotation unit providing the following treatment steps has been developed: (1) Chemical coagulation treatment as necessary, (2) introduction of bubbles, (3) flocculation, (4) flotation of solids and downflow of clear liquid, (5) clarified liquid overflow, and (6) removal and discharge of floated solids.

Many difficulties were encountered in the development of a suitable method of bubble production. This was finally accomplished after recognition of the relations between surface tension and bubble size. The result was a flotation unit which is practical, reliable, and requires little operating labor and maintenance. The air diffusion assembly cannot plug and will foul only over a long period of time.

The flotation unit can handle flow rates of 3 to 6 g.p.m. per square foot. Sludges recovered have varied from as low as

2 per cent dry solids to as much as 90 per cent (liquid fat separation).

This flotation process has been tested on a pilot-scale basis in connection with board mill, tissue mill, glue plant, and laundry wastes. Full-scale installations have included soap wastes, papermill white water, and oil in oil refining wastes.

PAUL D. HANEY

The Disposal of Plating Shop Effluents. BY A. E. J. PETTET. *Jour.*, Electrodeposition Tech. Soc. (British), **25**, 1 (1950).

Wastes from electroplating operations containing chromates, cyanides, and salts of heavy metals, are usually acidic and are not suitable for untreated discharge to an inland stream, as they may damage sewers and biological sewage treatment processes. The principal contaminated waste is that derived from preparatory cleaning of objects to be plated. Concentrations of these wastes vary from plant to plant, and from hour to hour in the same plant. At times, spent cleaning, pickling, or plating solutions have to be discarded. Volumes of these wastes are small, but often they contain high concentrations of poisonous inorganic compounds.

The effects of plating wastes on streams are related principally to their toxicity. Aquatic life may be destroyed and the water rendered unfit as a source of public supply. These wastes also may interfere with use of the stream for agricultural purposes and cause corrosion of structures.

As far as sewage treatment is concerned, interfering concentrations of most of the constituents are in the order of 1 or 2 p.p.m. However, somewhat higher concentrations in sewage may be tolerated without a complete treatment plant breakdown.

Acidic wastes containing simple metallic salts can be satisfactorily treated by addition of lime. Chromic acid and chromates can be removed by reduction with ferrous sulfate followed by lime precipitation as barium chromate. Cyanides can be removed by lime-ferrous sulfate treatment to precipitate insoluble complex cyanides or by chlorination in alkaline solution. Careful control of the latter process is necessary. Cyanide wastes should be segregated. Nickel and too much dilution interfere with their treatment.

Discussion. Discussions of this paper made reference to the extensive investigations being conducted by the American Electroplaters Society; to the difficulty of waste analysis in small plants; and the toxicity of an excess of barium chloride if the latter is used for chromate precipitation. Reference was also made to the electrolytic and formaldehyde processes of treatment of cyanide wastes. Limiting concentrations in sewer systems received consideration, and it was mentioned that a small plating works discharging 1,000 g.p.d. could be allowed more freedom than a larger plant discharging 200,000 g.p.d. It was emphasized that fatal accidents caused by toxic vapors in sewers have occurred. In his summary, the author mentioned that recovery of chromium by the roasting method was not practiced in Britain. Two firms have collected chromate wastes containing less than 3 per cent chromium. Although not stated, the inference is that these firms recovered the chromium and used it in leather tanning.

PAUL D. HANEY

Summary Report on Water Pollution Tennessee River Drainage Basin. U. S. Public Health Service Publication No. 69 (1951).

This is the first in a series of summary reports on the major drainage basin areas of the country under preparation by the Public Health Service under authority of the Water Pollution Control Act of 1948. Because the reports are prepared largely on the basis of information supplied by the states, it is pointed out that they do not present complete summaries of the pollution situation in each drainage basin, although they show where pollution control measures are needed for municipalities and industries.

In the Tennessee River valley, sewage and waste treatment projects estimated to cost more than $57,000,000 are needed at 227 municipal and industrial locations. Initial cost of required municipal treatment plants will be approximately $15,400,000; the cost of interceptors is estimated at about $26,300,000. Based on limited data, initial costs of industrial waste treatment, exclusive of industrial waste now discharged to municipal sewer systems, will be between $5,000,000 and $10,000,000.

Some 201 cities, towns, or other municipalities, and 148 industries are discharging significant amounts of pollution into the streams of the basin, mostly in the headwaters reaches, with industrial wastes accounting for at least two-thirds of the total organic load. For the purposes of reporting sources and quantities of pollution in the basin, the area was divided into eight major wastersheds or sub-basins. Of the 201 municipal sources of pollution, 122 discharge untreated sewage from 80 per cent of the basin population served by sewers. Moreover, although 57 municipalities have primary treatment works and 21 have secondary treatment works, only 32 treatment plants are considered satisfactory. These plants serve only 8 per cent of the sewered population in the basin. Only 13 of the 148 industries discharging wastes independently, rather than through public systems, have aedquate treatment facilities.

H. P. Orland

Abattoir Waste Treatment. By Robert E. Stiemke. Jour. Inter-American Assn. of San. Eng., **2**, 4,307 (Apr., 1949).

This report defines the problem, briefly reviews types of treatment, and describes study at the Pennsylvania State College pilot plant. In the review of treatment only a few results and but little description are given.

The pilot plant consisted of a holding-settling tank and facilities for four types of treatment. Chemical treatment was done in a batch-type tank with sludge disposed of to drying beds. Best B.O.D. reductions, which ranged from 95 to 97 per cent, were obtained by using 3.5 to 7 lb. of chlorinated lime (35 per cent) and approximately 5 lb. of alum per 1,000 gal. Dried sludge was extremely stable.

Sand filtration was tried on circular and rectangular filters using various means of distribution. With a hydraulic loading at 50,000 g.p.a.d. and a B.O.D. load about ten times that recommended for treating domestic sewage, reductions of 60 to 90 per cent were obtained for single-stage operation and over 90 per cent for two-stage operation.

Work was done on four small trickling filters operated with and without recirculation, single- and two-stage, and at rates ranging from 2 to 15 m.g.a.d. Maximum B.O.D. reduction obtained was 27 per cent. Aeration by mechanical means or diffused air failed entirely. Intermittent operation of the slaughterhouse and inclusion of blood explain in part the results obtained.

Wm. A. Hasfurther

Houston Sludge Disposal Plant Profits from Use of Existing Facilities. By J. G. Turney, S. A. Greeley, and P. E. Langdon. *Civil Eng.* **21**, 5, 26 (May, 1951).

This article gives general considerations and basis for the selection and design, and describes Houston's sludge drying plant. Of six methods of disposing of raw sludge investigated, that of utilizing the present sludge lagoons and drying the remainder for sale as fertilizer was chosen. Sludge is pumped to one of the two disposal plants, conditioned by means of ferric sulfate or ferric chloride, dewatered on four 11.5-ft. diameter vacuum filters, and dried in a flash-type unit. Plant drying capacity is about 61 tons of sewage solids per 24 hr.

Wm. A. Hasfurther

Proceedings of the Third National Public Health Conference. Bull. Series No. 42, Florida Eng. and Indus. Exper. Sta. (Apr., 1951).

Several papers were presented under the general theme "Suburban Sanitary Services." The first group of eight papers deals with special problems in suburban areas as seen from legal, developmental, financial, and governmental viewpoints. Solutions to the problems, from the viewpoints of city and suburban planning, sanitary district planning, and substitute measures, are discussed in a second group of four papers. In general, the problems discussed are peculiar to the Florida area.

H. P. Orland

A Bacteriological and Chemical Study of the Shore Waters of Biarritz (France). By L. Souchard, P. Andrieu, and M. Darmendrail. *Tech. Munic. et Sanit.* (France) **46**, 72 (Mar., 1951).

This is a study promoted by the French Ministry of Reconstruction and City Planning of the effects of sewage disposal at sea by the city of Biarritz; the outfall is an open sewer ending in a dike-protected cove. Analyses at various points within a radius

of 1.0 km. show the following (5 samplings between Nov., 1949, and May, 1950): minimum D.O., 5.7 p.p.m.; NH_3-N varying from 0 to 12 p.p.m. (average 0.1 p.p.m.); *B. coli* and *Salmonellae* decreasing sharply from 500,000 per l. to 25,000 per l. within a 450-m. radius, and practically none farther away. The sea currents seem to prevent (up to a point) contamination of the nearby bathing beaches and dilution is a factor in this purification, but the main cause of bacterial decrease is described by the authors as "the anti-biotic power of sea water," countering Imhoff's belief that self-purification of sewage proceeds faster in river water than sea water. The authors conclude that Biarritz beaches are quite safe, but recommend that sewage treatment (comminuting and settling, especially) be practised before disposal at sea.

MARC ALBANESE

Experiences and Viewpoints on the Discharge of Sewage at Sea and in estuaries in Holland. BY M. HOPMANS. *Tech. Munic. et Sanit.* (France) **46**, 65 (Mar., 1951).

Analyzing the various methods of sewage disposal at sea practised in Holland, the author comes to the following conclusions: Outfalls in rivers or canals create immediate nuisance in harbors and beaches (grease, odors, and bacterial pollution). Submarine outfalls 1 or 2 mi. at sea for finely screened sewage do not prove too efficient, due to the tendency of substances to float (oil, etc.), even when adequate mixing with sea water is provided; beaches are still polluted appreciably with bacteria and oil, unless permanently favorable winds and sea currents are present. Dumping of sewage and industrial wastes in certain wide estuaries, somewhat similar to lakes, is permissible, if no bathing or shellfish culture is involved, and if a minimum D.O. of 5 p.p.m. is maintained. The following formulas are proposed to calculate if such conditions can be achieved in an estuary:

$$G = [(C_i - 5)\, q\, 1{,}000] + [(C_v - S)\, A\, O],$$

and

$$C_z = \frac{(1{,}000\, C_i\, q) + (C_v\, A\, O) - G}{1{,}000\, q + A\, O}$$

in which G = kg. B.O.D. per day applicable, maintaining, at a given temperature, 5 p.p.m. D.O. (minimum); C_i = p.p.m. D.O. of incoming river water; q = river flow, in millions of cubic meters per day; C_v = saturation D.O. at the temperature of observation; A = re-aeration coefficient; O = estuary surface area, in hectares; C_z = D.O. to be expected when discharging a given waste, the other factors being known. Oxygen produced by green algae is neglected, due to difficulties of evaluation. The Hollands Diep, used as an outfall by the city of Breda and many big sugar refineries, is such an example: its minimum D.O. content is 6.75 p.p.m.

MARC ALBANESE

Colorimetric Determination of Copper. BY R. HORVAI. *Anal. Chim. Acta*, **4**, 91 (1950).

A method is described for the colorimetric determination of copper, using as reagent 0.2 g. of the sodium salt of tetrabromophenolphthalein in 100 ml. of water. To 1 ml. of the sample is added 1 ml. of the reagent and the volume is made up to 5 ml. After standing for several minutes to allow the yellow color to develop, the extinction of the colored solution is measured with a photometer and the amount of copper present is determined by use of a calibration curve. Interference is caused by iron and aluminum.

H. P. ORLAND

Studies of Pollution in Streams of Alabama. Alabama Water Improvement Advisory Commission. 298 pp. (1949).

The stream pollution studies detailed in this report resulted from state legislation in 1947 and 1949 intended to further the objectives of pollution abatement and prevention. The studies included chemical, physical, and bacteriological analyses, as well as biological studies and industrial waste surveys.

The report presents in detail the summary data on the streams in the major drainage basins of the state and discusses these data in relation to present and potential water uses.

H. P. ORLAND

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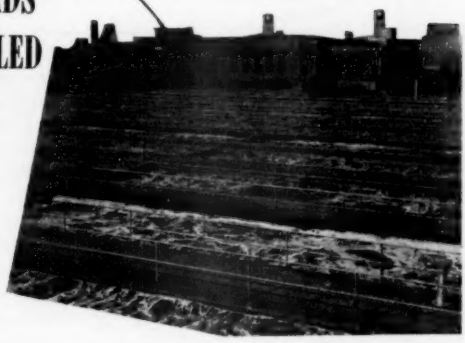


Activated sludge aeration tanks, Peoria, Ill. Three channels in foreground, out of a total of twelve aeration channels, are used for sludge nitrification.

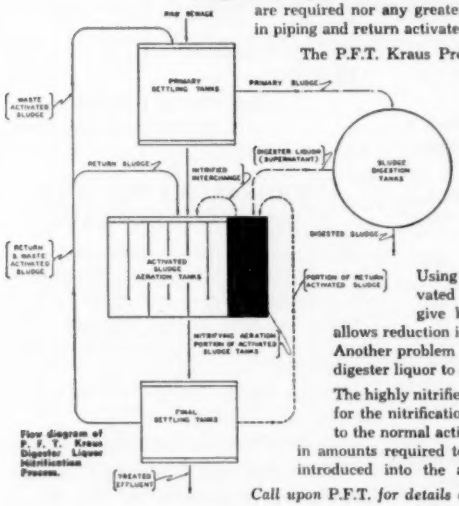
The P.F.T. Kraus Process, also known as the "Digester Liquor Nitrification Process," can be readily applied to existing plants or incorporated in the design of new plants. No additional aeration basins or aeration facilities are required nor any greater amount of air. Only a slight revision in piping and return activated sludge pumping facilities are required.

The P.F.T. Kraus Process provides these three plus values:

(1) Eliminates the need for expanding plant facilities by overcoming effect of greatly increased loads exceeding original plant capacity.

(2) Nullifies formerly disastrous effect of shock loads from industrial waste organic matter.

(3) Utilizes all digester liquor overflow to advantage in the main treatment process.



Flow diagram of P. F. T. Kraus Digester Liquor Nitrification Process.

Using this system, sludge produced in the activated sludge process settles more readily to give better overall results in purification or allows reduction in capacity of secondary settling facilities. Another problem is effectively overcome by making use of digester liquor to advantage.

The highly nitrified sludge from the aeration tanks set aside for the nitrification process may be returned continuously to the normal activated sludge process or may be returned in amounts required to balance shock loads or organic matter introduced into the aeration tanks.

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Proceedings of Member Associations

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

The 1951 Annual Meeting of the Arizona Sewage and Water Works Association was held at Grand Canyon, Ariz., March 28–30, 1951. Registration at the meeting totaled 155.

Papers read at the meeting included:

"Wood Preservation," by W. E. Hoyt, American Lumber and Treating Co., Los Angeles.

"Hydro-Pneumatic Pressure Tank Installation," by Harry S. Jordan, Arizona State Dept. of Health.

"Redevelopment of Water Wells by Vibratory Explosives," by Harvey Mylander, Water Supply Analysts, Los Angeles.

"Bladeless Sewage Pump," by A. M. McLaren, Fairbanks, Morse & Co., Los Angeles.

"Today's Trends and Tomorrow's Problems," by W. H. Wisely, executive secretary, FSIWA.

"Tucson Sewage Treatment Plant," by Charles E. Trygg, Arizona State Dept. of Health.

"Civil Defense and Sewage Systems," by A. M. Rawn, chief engineer, Los Angeles County Sanitation Districts.

"Civil Defense and Water Supplies," by Samuel B. Nelson, assistant chief engineer of water works, Los Angeles Dept. of Water and Power.

"Disposal of Wastes from Water Purification and Softening Plants," by W. W. Aultman, Metropolitan Water Dist. of Southern California.

"Biological Warfare," by H. G. Crecelius, Arizona State Dept. of Health.

"Protective Coating of Pipe," a symposium by N. K. Senatoroff and Roy Richards, respectively consulting chemical engineer, Southern Counties Gas Company of California, and superintendent of gas, Central Arizona Light and Power Co.

On March 30, members and guests had a delightful evening at the annual Dinner-Dance.

An inspection tour of the Grand Canyon sewage treatment plant on the morning of March 31 brought the conference to a close.

At the Business Luncheon on March 30, Sewage Works Section officers elected for 1951–52 were:

President: S. P. Henderson, Prescott.
1st Vice-President: M. V. Ellis, Phoenix.
2nd Vice-President: I. F. Brown, Williams.
Secretary-Treasurer: H. S. Jordan, Phoenix.

MRS. HELEN ROTTHAUS,
Secretary-Treasurer

ARKANSAS WATER AND SEWAGE CONFERENCE

With a near-record registration of about 180, the 1951 Annual Meeting of the Arkansas Water and Sewage Conference was held at Hot Springs, Ark., April 9–11, 1951. The meeting stressed particularly the preparation of water works personnel for the voluntary licensing examination.

Papers of general interest included:

"Financing and Budgeting for Major Capital Expenditures," by M. A. Mehlburger, consulting engineer, Little Rock.

"Public Relations," by A. Pollard, Little Rock.

"Pump Controls and Wiring," by

(*Continued on page 306a*)

Philadelphia's Independence Hall, where the Liberty Bell is housed, as it looked 100 years ago

Philadelphia has cast iron water and gas mains in service that were laid well over a century ago. One of them is America's oldest cast iron water main, still functioning despite the radically changed conditions of street traffic and underground utility services in 100 years. The fact that cast iron pipe, laid generations ago, withstands the shock of heavy-duty traffic and the stresses caused by congested underground structures, amply demonstrates its shock-strength and beam-strength. Because of these strength factors and effective resistance to corrosion, cast iron water and gas mains, laid over 100 years ago, are still serving in the streets of more than 30 cities in the United States and Canada. United States Pipe and Foundry Co., General Offices, Burlington, N. J. Plants and Sales Offices Throughout the U.S.A.

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C. H. LeVee, chief engineer, Fagan Electric Co., Little Rock.

At the sewage works session, on the afternoon of April 10, the following papers were presented:

"Practical Operation of a Sewage Treatment Plant," by H. R. Conway, sanitary engineer, Arkansas Pollution Control Commission, Little Rock.

"Future of Stream Polution," by E. C. Warkentin, Stream Pollution Division, U.S.P.H.S., Little Rock.

"Sewer Improvement Financing," by J. Stevens, W. R. Stevens Investment Co., Little Rock.

"Sewer Construction," by S. L. Davies, contractor, Little Rock.

A report on Federation activities was given by Earnest Boyce, FSIWA vice-president, at the Luncheon on April 10. The meeting proper closed with the Annual Dinner and Business Meeting on April 10.

Officers elected to serve during 1951–52 were:

Chairman: C. A. Brown, Pine Bluff.

Vice-Chairman: J. J. Highfill, Springdale.

Secretary: Harrison Hale, Magnolia.

HARRISON HALE,
Secretary

KANSAS SEWAGE WORKS ASSOCIATION

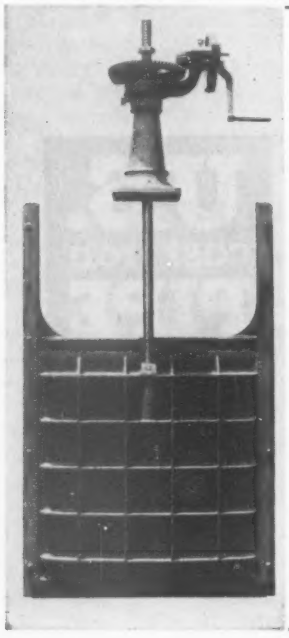
The Sixth Annual Joint Meeting of the Kansas Sewage Works Association and the Kansas Section, AWWA, was held at the Lamer Hotel, Hays, Kansas, April 11–13, 1951. Registration for the meeting totaled 201.

On the afternoon of April 11 concurrent round tables were held by the Water Section and the K.S.W.A. The latter met at the Hays sewage treatment plant to hear discussions as follows:

"Problems of Starting a New Sewage Treatment Plant," by Ben Etnire, superintendent, Augusta.

"Problems Connected with a New Sewer System," by Leland Talbot,

(*Continued on page 308a*)



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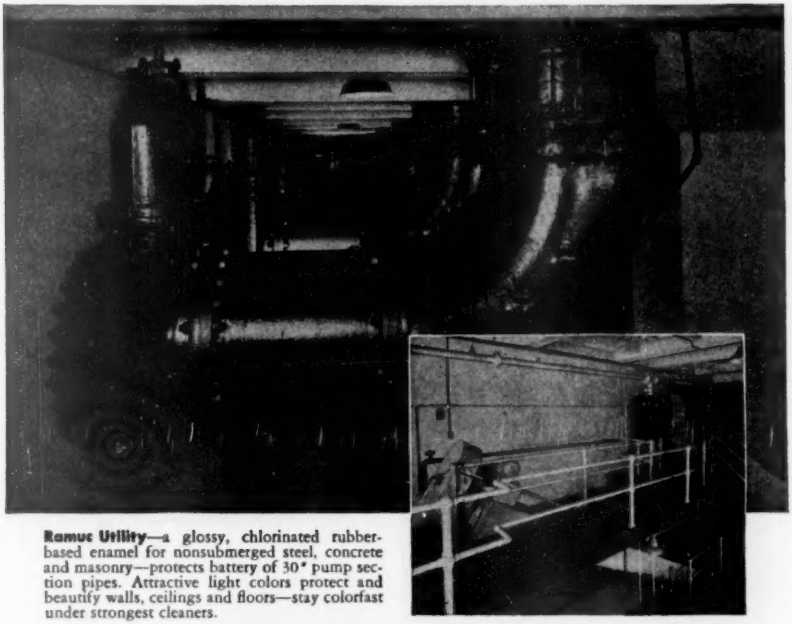

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superintendent, Greenleaf.

"Health Considerations in Operating a Sewage Treatment Plant," by G. E. Mau, Kansas State Board of Health.

"Increasing the Capacity of an Activated Sludge Plant by Stage Aeration," by D. B. Kissinger, superintendent, Topeka.

"Maintenance of Gas Collection Equipment," by E. C. Cardwell, The Dorr Company, Chicago.

"Problems of Building New Sewers and Their Maintenance," by M. K. Nelson, chief engineer, Mission Township Sewer District No. 1.

"Effect of Material Shortages on the Design and Construction of Sewage Treatment Plants," by L. W. Servis, consulting engineer, Topeka.

This was followed by an inspection tour of the Hays sewage treatment plant for the combined groups and a demonstration of sewer cleaning by Alden Smith, consulting engineer, Kansas City, Mo.

During the general sessions on April 12, greetings were extended by A. E. Berry, AWWA vice-president, and Earnest Boyce, vice-president of the Federation. Papers presented included:

"Water Chlorination in Principle and Practice," by H. A. Faber, research chemist, The Chlorine Institute, New York City.

"Chlorinating Practices and Installations in Kansas," by L. H. Petersen and J. Gyulay, Jr., Wallace & Tiernan Sales Corp., Kansas City, Mo.

"Maintenance of Electrical Controls and Equipment in Water and Sewage Plants," by M. DeNeui, Black & Veatch, Kansas City, Mo.

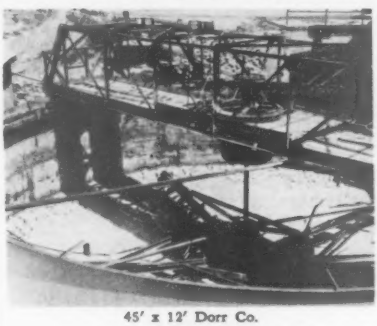
"Standardized Mechanical Joint Cast Iron Pipe," by T. F. Wolfe, managing director, Cast Iron Pipe Research Assn., Chicago.

"Maintenance and Operation of Settling Tanks," by W. N. Konrad, Chain Belt Co.

(*Continued on page 310a*)

IMMEDIATE DELIVERY

9 Thickeners and Clarifiers



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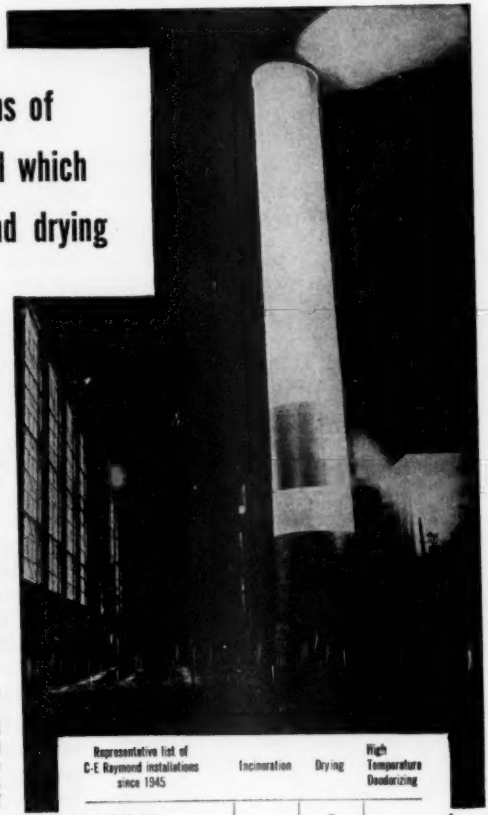

As will be seen by the list at the lower right, there have been seven major installations of C-E Raymond Systems in the last five years which combine the two usual disposal methods . . . drying and incineration. The C-E Raymond System usually provides for high temperature deodorizing employing preheater equipment to save fuel and assure low stack temperatures.

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The session closed with a round table, at which J. J. Tepas, Mathieson Chemical Corp., Syracuse, N. Y., described a new method of hypo-chlorination, and W. H. Dominick, Wichita Meter Supply and Repair Co., and A. P. Flynn, meter service superintendent, Wichita Water Company, discussed water meter maintenance and repair.

At the Annual Banquet, held the evening of April 12, the speaker was M. C. Cunningham, president of Kansas State College.

The morning session on April 13 featured the following papers:

"Fluoridation of Public Water Supplies," by Dwight Metzler, chief engineer, Kansas State Board of Health.

"Thirty Years of Progress in Sewerage Practice," by Earnest Boyce, chairman, Department of Civil Engineering, University of Michigan.

"Maintenance of Raw Water Quality Standards," by A. E. Berry, director, Sanitary Engineering Division, Ontario (Canada) Department of Health.

"Civilian Defense," by Standish Hall, state director of civilian defense, Wichita.

At the Business Meeting following luncheon on April 13, Roy Binder, superintendent, sewage treatment plant, Hays, was nominated to receive the Federation's Bedell Award. The following officers were elected for 1951–52:

Chairman: L. Talbot, Greenleaf.
Vice-Chairman: H. L. Ramage, Lyons.
FSIWA Director: G. E. Mau, Lawrence.
Secretary-Treasurer: D. F. Metzler, Lawrence.

The meeting closed with an inspection trip to the new municipal water softening plant at Hays.

DWIGHT F. METZLER,
Secretary-Treasurer

MONTANA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 7th Annual Meeting of the Montana Sewage and Industrial Wastes Association was held at the Placer Hotel, Helena, Mont., April 19, 1951. Registration totaled 65.

The one-day technical program included major committee reports on "Standard Practices in the Design, Construction and Maintenance of Sanitary Sewer Systems in Montana" and the "School for Water and Sewage Works Operators and Managers," as well as a report on activities of the Federation, by W. H. Wisely, FSIWA secretary, and a discussion of "Control of Water Pollution—A Report of the President's Water Resources Policy Commission," by R. R. Renne, who is a member of the Commission and president of Montana State College.

The afternoon session opened with a paper on "Financing of Municipal Sewage Works Improvements," by D. R. Smith, city attorney, Helena, after which a panel discussion was scheduled "to consider all aspects of municipal sewage collection and sewage and industrial wastes treatment and disposal." Topics covered included household garbage grinders, oil control, house connections, groundwater infiltration, and sewer design and construction standards.

At the business session the name of the Association was changed to Montana Sewage and Industrial Wastes Association. Officers elected for 1951–52 were:

Chairman: R. Preator, Helena.
Vice-Chairman: S. B. Ward, Billings.
Secretary-Treasurer: H. B. Foote, Helena.

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Upper photo shows completed section of reinforced concrete box sewer, 7 ft. high x 16 ft. wide, before backfilling. Lower photo shows 66-in. reinforced concrete pipe being placed in a 24-ft. cut.

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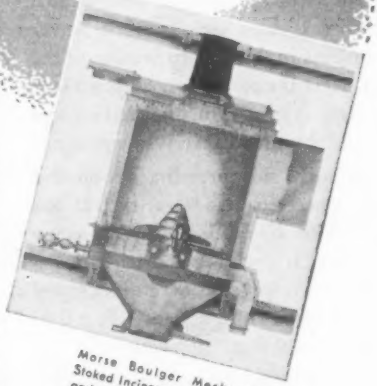

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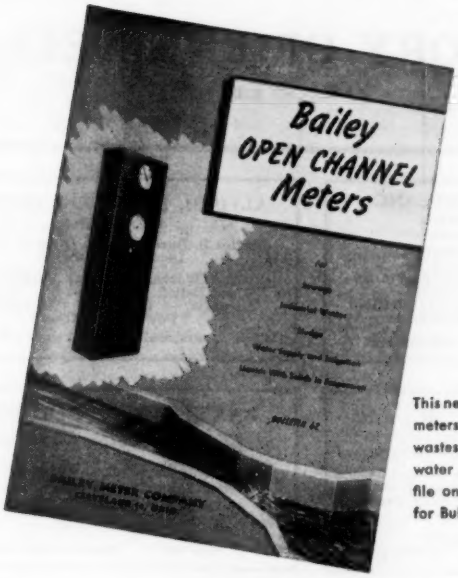

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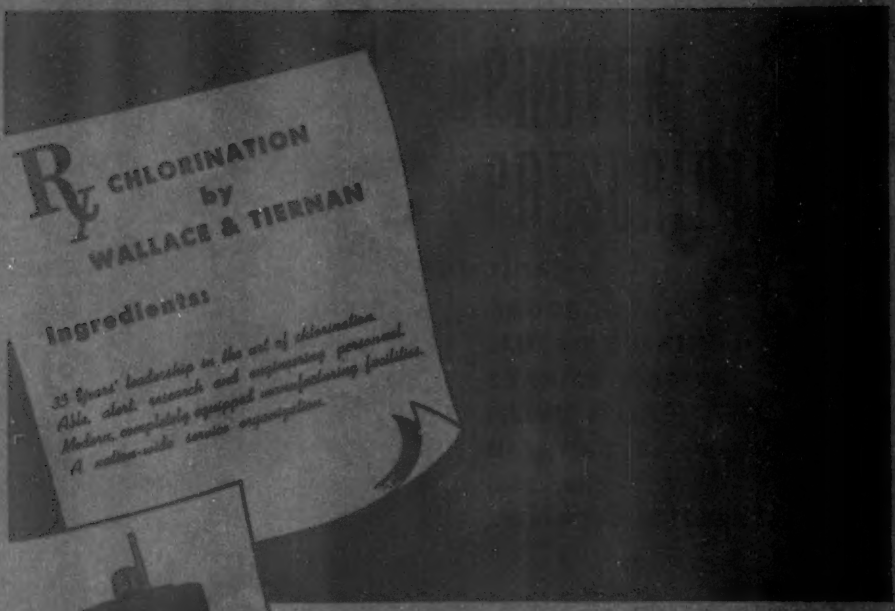

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